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INSTRUCTIONS

GENERADOR
UNIDADES
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LARGE VERTICAL SYNCHRONOUS MACHINES

GENERAL ELECTRIC

This book is intended to give helpful suggestions for assembling and erecting the machine, for preparing it to go into service, for its operation, and for a program of inspection and maintenance to promote long, trouble-free life of the equipment. The applicable sections should be studied in advance.

Be sure that the operator of the equipment has a copy of this Instruction Book.

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

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LARGE VERTICAL SYNCHRONOUS MACHINES

PREPARATION FOR INSTALLATION

1-1 GENERAL

Machines should be installed where they will be protected from moisture, escaping steam, drip from pipes, and any acid, alkali, oil, or gas, as well as from dust, dirt, lint, or other injurious substances.

1-2 RECEIVING AND STORAGE

The equipment should be placed under adequate cover immediately upon receipt. Packing cases are **not** suitable for outdoor or unprotected storage.

Each shipment should be carefully examined upon arrival. Any damage should be reported promptly to the carrier and the nearest office of the General Electric Company.

Equipment which is not to be installed immediately should be stored under cover in a clean, dry place and protected from low temperatures and rapid or extreme variations in temperature or humidity. Windings should be protected from rodents and termites. Machined parts such as journals, bearings, fitted surfaces, etc., are coated with a protective compound before shipment to prevent rusting. If there are signs of damage to these parts, the protective compound should be removed as described in Sect. 1-3. Any rust or moisture should be removed and the surfaces reslushed. Reslushing will not prevent rusting unless all traces of rust and moisture have been removed.

During storage, the windings should be protected against sweating and freezing by some safe and reliable heating system which will always keep the temperature of the machine above the dewpoint of the surrounding air. An electric heater and fan with thermostatic control is excellent.

For disassembled, wound stator sections, assembled rotors, or poles, 15 watts per 1000 pounds should be satisfactory if applied inside the crates.

Machines in storage should be inspected, and the windings meggered at frequent and periodic intervals. A log should be kept of the pertinent data. Any significant drop in insulation resistance should be investigated. More heat may be required to limit moisture absorption.

Experience has shown that adequate precautions during storage will avoid costly deterioration of parts and abnormally long dryout time after installation.

1-3 UNPACKING

If the coils or parts with machined surfaces have been exposed to a low temperature, do not remove their coverings until they have warmed to approximately the temperature of the room where they are to be unpacked, or they will sweat.

Slushing compound can be readily removed by using kerosene or a commercial solvent with some oil added. Use hair-bristle paint brushes or clean rags (not cotton waste or synthetic-bristle brushes).

> **CAUTION:** *Most cleaning fluids are inflammable or toxic. Read the discussion in Sect. 6-4 before using cleaning solvents.*

Journal and bearing surfaces should be cleaned and checked only by experienced personnel.

Do not use sandpaper or any abrasive or metallic scrapers to clean finished surfaces. After the finished surfaces have been thoroughly cleaned, carefully remove with a fine file, scraper, or stone any burrs or bumps received in shipping.

1-4 HANDLING

Machines or parts of machines must be handled carefully to prevent damage to the windings or other parts.

When lifting stator frames, the slings should be so arranged that the weight is supported by the lifting bars and **not** by the spacer bars or clamping bars.

Never support shafts on the journal surfaces. To move a rotor with the shaft horizontal the slings should be passed around the shaft. (On long machines it may be desirable to pass the slings around the outer periphery of the poles). Proper blocking for protection should be used in either case. With the shaft vertical, rotors may be handled by slings through the spider. Tapped holes in the end of the shaft must not be used for lifting a complete rotor, but are sometimes used for attaching a device for handling the shaft only. A lifting trunnion, as shown in Fig. 1-1, is sometimes supplied for up-ending and

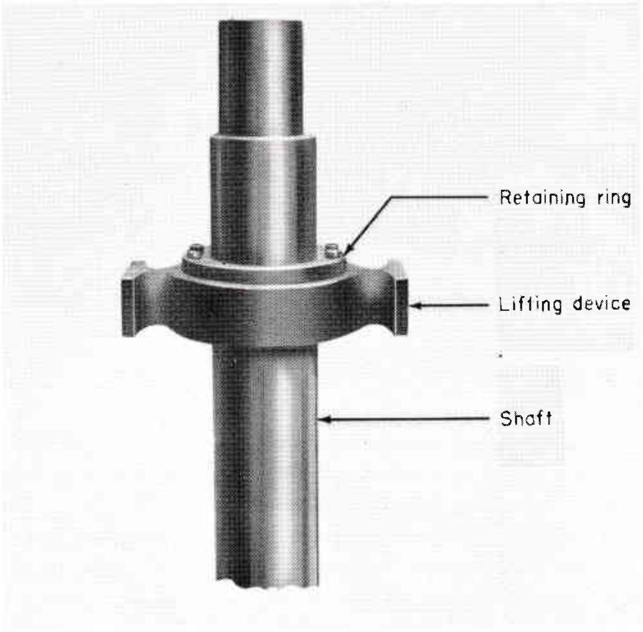


Fig. 1-1. Device for lifting the rotor.

handling the complete rotor. The trunnion usually fits on the shaft in the place normally occupied by the thrust collar. It is held in position by a circular key which fits in a groove in the shaft.

1-5 CLEANLINESS

The coils, ventilating ducts, commutators, etc. should be shielded from dirt or other extraneous material. Particular pains should be taken to exclude metal chips, filings, weld splatter or other foreign materials from the windings as well as from all parts of the machine. If construction work is going on, or the erection floor is exposed to weather, all parts should be covered to exclude dust and water.

1-6 VENTILATION PROVISIONS

The ventilation system must provide an adequate quantity of cool, clean, dry air as well as a means of discharging the hot air exhausted from the machine.

Dirt deposited on the windings and in the ventilating ducts of the core decreases the quantity of air passing through the machine. This increases the temperature rise of the machine, thereby reducing the safe operating capacity and the life of the insulation.

If the machine is designed to take in air from the pit, suitable ducts must be provided in the foundation. The machine outline drawing shows the approximate size of the pit and gives information for determining duct sizes. The ducts should be as short and straight as possible. Provision must be made to keep the hot, outgoing air from mixing with the cooler, incoming air. Where the cooling air is drawn from outside the station, provision should be made for adequate openings for incoming air as well as for adequate fixed openings to permit free discharge of air out of the station.

If specific information is not available, the approximate, allowable pressure drop for the ventilating system is

$$h = 0.05\left(\frac{D\,N}{1000}\right)^2$$

where h is the allowable pressure drop in inches of water.
D is the stator-bore diameter in feet.
N is the rated speed in rpm.

When concrete foundations are used, the elevation should be such as to allow for one to two inches of grout between the foundation and the foundation caps. Provision should also be made for grouting the lugs on the air housing curb ring and the lower deck-plate ring.

1-7 FOUNDATIONS

The foundation should be substantial and rigid. It should be constructed of reinforced concrete, or steel girders of sufficient stiffness to insure freedom from vibration. It should be designed to support the weights and other forces of the various parts of the machine as shown on the outline drawing.

1-8 FOUNDATION BOLTS

Accurate location of foundation bolts is essential. A good way to set these bolts is to locate them by means of a template when pouring the foundation. They may also be set in pipes or tapered pockets which are somewhat larger than the bolts to allow for slight variations in the final position. These sleeves or pockets should be filled with concrete after the final location of the bolts is fixed. To assure good bonding, both bolts and sleeves should be left unpainted.

MACHINE ASSEMBLY AND ALIGNMENT

2-1 GENERAL

The method of installation may vary considerably depending on the size and type of machine and the station layout. Only the general procedures are outlined here, and all components or operations mentioned may not be present in a particular machine.

When reference is made to a generator or a turbine in this section, it can be assumed to apply equally well to a motor or a pump.

The reference lines for assembly and preliminary alignment are the axial center line, the radial assembly line, and the **top** of the stator frame.

Attention must be paid to the match-marks on all pieces. When more than one unit is furnished, each machine should be assembled of parts having the same serial number. (Separate numbers are given stator and rotor but those for one machine customarily have the same two final digits.) Disregard shop-order numbers.

Before generator erection may be started, the turbine shaft must be plumb and centered to the turbine-guide-bearing support. It must also be at an accurately known distance from its final elevation.

NOTE: *Before assembly of any component, read the discussion of that component in Sect. 3.*

2-2 A MACHINE WITH THE THRUST BEARING ABOVE THE ROTOR

The following is a typical installation procedure for a machine with the thrust bearing above the rotor:

1. Place the foundation caps for the stator frame and the lower bearing bracket at approximately the correct positions and elevations and level them (do not grout).
2. Place the lower bracket in a temporary location on its foundation caps.
3. Place the stator sections on the foundation caps, align the joints, and install the joint bolts. Fasten the stator frame to the foundation caps by means of the stator holding-down bolts.
4. Align the frame sections carefully, shrink the stator-joint bolts, and install the stator-joint dowels.
5. Start installing the stator-joint coils (this can be carried on simultaneously with other work until the rotor is placed in the machine).
6. Adjust the stator elevation to bring the **top** of the stator frame to the elevation determined from the outline drawing. This is done by placing shims or sliding parallels between the foundation caps and the foundation. Carefully level and round-out the stator and tighten the stator foundation bolts.
7. Place the upper bracket on the stator frame and adjust it to approximately the correct

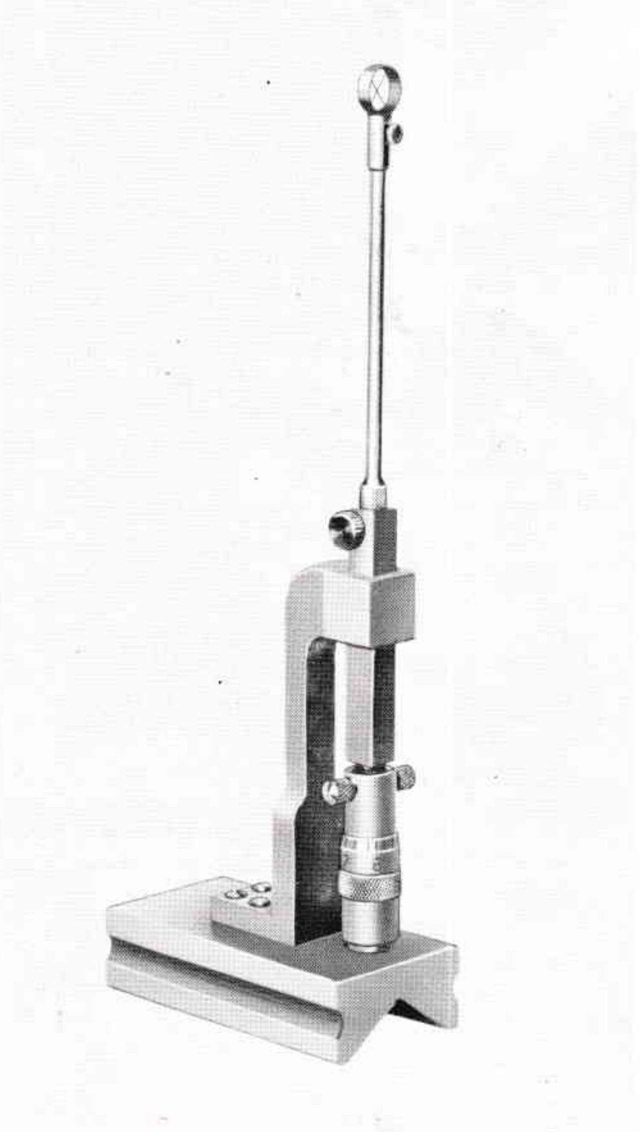


Fig. 2-1. Micrometer-type wye-level target for use in leveling machine components.

height above the turbine coupling by means of shims under the ends of the arms.

8. Hang a plumb line from the center of the upper bracket to the turbine shaft. Center the bracket to the stator, and install temporary dowels between the bracket and the stator frame. The temporary dowels are to facilitate reassembly.
9. Center the assembly of stator and upper bracket to the turbine shaft.
10. Adjust the elevation of the lower bracket by means of shims or iron blocks under the foundation caps so that the guide bearing will be axially located on its journal. Center the lower bracket to the turbine shaft and tighten the lower bracket foundation bolts.
11. Remove the upper bracket.
12. Place the rotor in the machine and support it on the jacks.
13. Replace the upper bracket, coat the bearing surfaces with Gredag, and assemble the thrust bearing and thrust collar.
14. Lower the rotor onto the thrust bearing, and level the upper bracket by means of shims under the arms (a check should be made at this time to be sure that the rotor will be approximately, vertically centered in the stator).

    The bracket should be adjusted until the generator shaft is plumb while being freely supported by the thrust bearing.
15. Align the generator coupling to the turbine coupling and pull the two couplings together.
16. Finish the coupling-bolt holes and install and tighten the coupling bolts.
17. Check the straightness of the combined shafts.
18. Plumb the shaft, center it to the turbine, and establish trammel points at all guide bearings (including the turbine guide bearing).
19. Check the axial position and centering of the lower guide-bearing support. Readjust the bearing bracket position if necessary.
20. Install the guide bearings. If sleeve type bearings are used check the clearances all around the journal. This may require recentering the bearing support and/or bracket. If segmental bearings are used, adjust to the correct clearance. Install the upper guide first, the lower guide next, and the turbine guide last. Check the trammel points at the turbine guide bearing after installing each bearing to be sure that the shaft has not shifted.
21. Check the air gap for uniformity.
22. Dowel the upper bracket to the stator frame, and dowel the lower-bracket and stator-frame to the foundation caps.
23. Grout the foundation caps.

Some smaller machines are built with the lower bracket bolted or welded to the stator frame. These machines may be installed using the above procedure by omitting steps 2, 3, 4, 5, 10 and 19.

2-3 A MACHINE WITH THE THRUST BEARING BELOW THE ROTOR

The following typical installation procedure applies to a machine with the thrust bearing below the rotor:

1. Set the foundation caps for the stator frame and the lower bearing bracket at approximately the correct elevation. Level them and grout the lower-bracket foundation caps.
2. In the erection area, make up the assembly of the lower-bracket, shaft, thrust bearing, and lower guide bearing.
3. Tighten four guide-bearing segments against the journal to keep the shaft in position and place the complete lower-bracket assembly in an approximate location on its foundation caps.
4. Place the stator sections on the foundation caps, align the joints, and install the joint bolts. Fasten the stator frame to the foundation caps by means of the stator holding-down bolts.
5. Align the frame sections carefully, shrink the stator-joint bolts, and install the stator-joint dowels.
6. Start installing the stator-joint coils (this can be carried on simultaneously with other work until the rotor is placed in the machine).

7. Plumb the shaft and bring the coupling to the proper elevation by means of the jack screws on the lower-bracket arms.
8. Align the generator coupling to the turbine coupling and pull the two couplings together.
9. Finish the coupling-bolt holes and install and tighten the coupling bolts.
10. Check the straightness of the combined shafts.
11. Plumb the combined shafts (with the weight supported by the thrust bearing) and center them to the turbine. Establish trammel points at the turbine guide bearing and the generator lower-guide bearing.
12. Fit and install the chocks between the lower-bracket arms and the foundation caps.
13. Re-check the plumbness of the shaft and center it to the turbine.
14. Carefully level and round out the stator with the **top** of the frame at the elevation determined from the outline drawing. Center the stator around the shaft and tighten the stator foundation bolts.
15. Place the assembly of rotor-spider, rim, and poles in position on the generator shaft.
16. Carefully center the rotor assembly around the shaft and install enough temporary hub bolts to hold it in place.
17. Finish the rotor-hub-bolt holes and install and tighten the hub bolts.
18. Re-plumb the shaft (with the rotor weight being supported by the thrust bearing) by adding balance weights to the rotor spider.
19. If the rotor is approximately vertically centered in the stator, grout the stator foundation caps.
20. Install the upper bracket and center it to the shaft.
21. Axially locate and align the upper-guide-bearing support by placing shims under the upper-bracket arms. Establish trammel points at the upper guide bearing.
22. Adjust the clearance of the generator lower-guide bearing. Install and adjust the turbine guide bearing and the generator upper-guide bearing, and re-check the trammel points to be sure the shaft has not shifted.
23. Check the air gap for uniformity.
24. Install the dowels between the upper bracket and the stator frame, between the stator frame and the foundation caps, and between the lower bracket and the foundation caps.

NOMENCLATURE FOR FIG. 2-2

1. Shaft
2. Lower oil pan
3. Sleeve-type lower guide bearing
4. Lower oil guard
5. Web-plate rotor spider
6. Rotor coil
7. Fan
8. Field leads
9. Stator frame
10. Clamping finger
11. Stator coil
12. Air deflector
13. Cooling coil
14. Bearing temperature device
15. Radial-arm upper bearing bracket
16. Upper guide-bearing support
17. Sleeve-type upper guide bearing
18. Upper oil guard
19. Thrust collar
20. Thrust-bearing runner
21. Thrust-bearing stationary segment
22. Railing
23. Exciter stator frame
24. Exciter main-field coil
25. Exciter rotor spider
26. Exciter rotor coil
27. Brush holder yoke
28. Commutator brush rigging
29. Collector ring
30. Collector brush rigging
31. Stator key bar
32. Stator ventilating duct
33. Stator core
34. Stairway
35. Lifting bar
36. Lower bearing bracket
37. Pole bolt
38. Bottom insulating collar
39. Top insulating collar
40. Bolted rotor pole

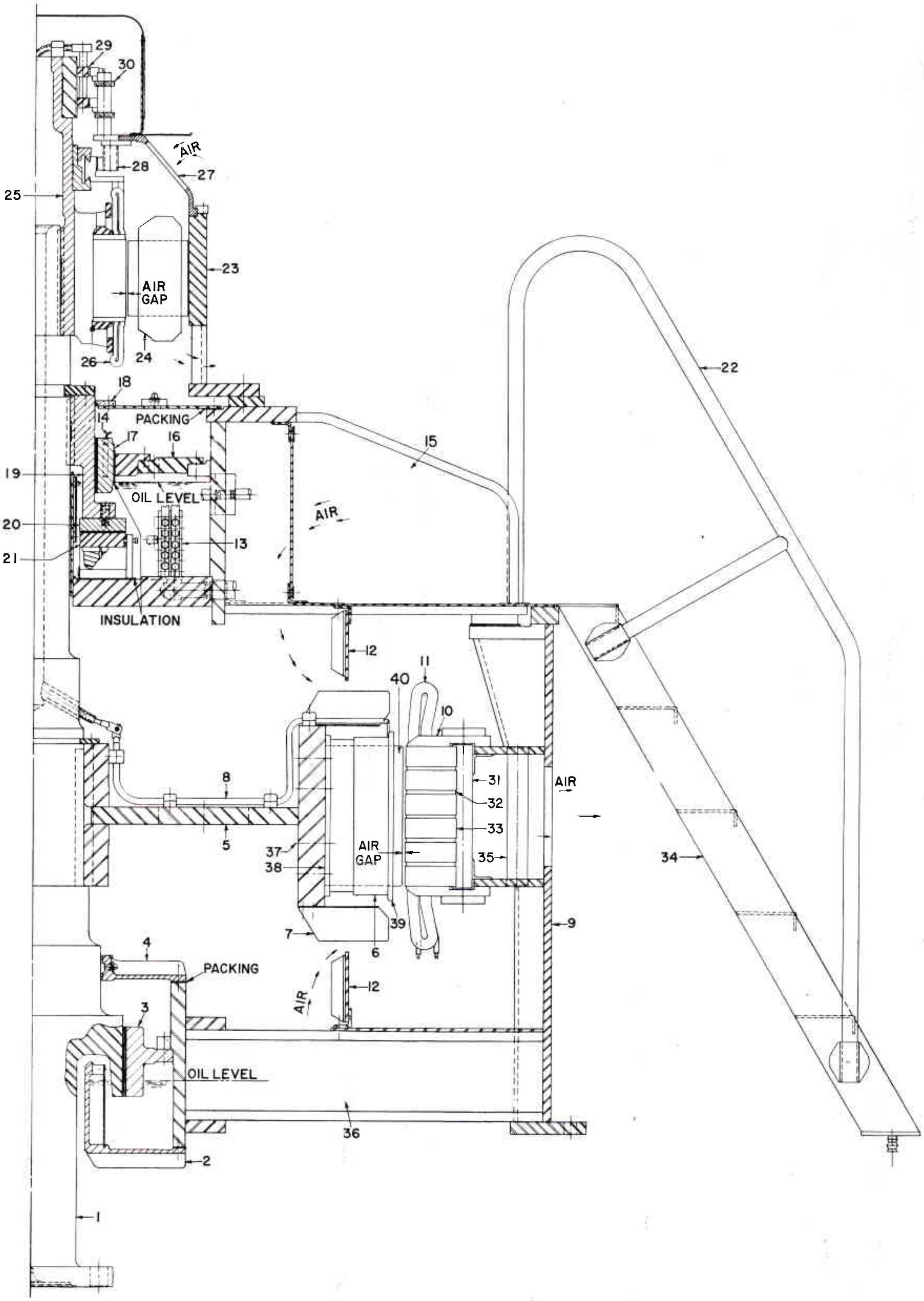


Fig. 2-2. A typical motor (1250 hp and 225 rpm) with a combined guide and thrust bearing above the rotor. The lower bearing bracket is integral with the stator frame, and the rotor-spider consists of a rolled rim and a hub which are welded to a web plate.

NOMENCLATURE FOR FIG. 2-3

1. Shaft
2. Lower oil pan and cooling coil
3. Radial-arm lower bearing bracket
4. Retaining plate
5. Sleeve-type lower guide bearing
6. Lower oil guard
7. Upper oil guard
8. Brake and jack
9. Stator key bar
10. Lower cover plates
11. Air baffle
12. Lower-bracket foundation cap
13. Air deflector
14. Stator foundation cap
15. Stator frame
16. Stator core
17. Stator winding support (binding band)
18. Stator coil
19. Rotor coil
20. Punched-plate rotor spider
21. Field leads
22. Rotor-pole end plate
23. Rotor-spider retaining ring
24. Dovetailed rotor pole
25. Parallel-arm upper bearing bracket
26. Bearing oil cooler
27. Thrust-bearing spring cage
28. Thrust collar
29. Guide bearing support
30. Sleeve-type upper guide bearing
31. Clamping finger
32. Thrust-collar retaining ring
33. Collector brush rigging
34. Collector ring
35. Thrust-bearing stationary segment
36. Thrust-bearing runner
37. Brake plate
38. Stator ventilating duct
39. Main exciter support
40. Air cooler support
41. Air cooler
42. Air housing
43. Stairway and handrail
44. Foundation bolts
45. Foundation bolt plates
46. Main-exciter commutator
47. Pilot-exciter shaft
48. Main-exciter stator frame
49. Pilot-exciter stator frame
50. Main-exciter rotor spider
51. Pilot-exciter rotor spider
52. Main-exciter brush rigging
53. Pilot-exciter brush rigging
54. Pilot-exciter commutator
55. Main-exciter field pole
56. Pilot-exciter field pole
57. Main-exciter field coil
58. Pilot-exciter field coil
59. Main-exciter rotor coil
60. Pilot-exciter rotor coil
61. Oil expansion tank
62. Air cooler piping
63. Permanent-magnet generator
64. Round lifting bar
65. Angle-iron spacer bar
66. Fan
67. Top insulating collar
68. Bottom insulating collar
69. Thrust-bearing base plate

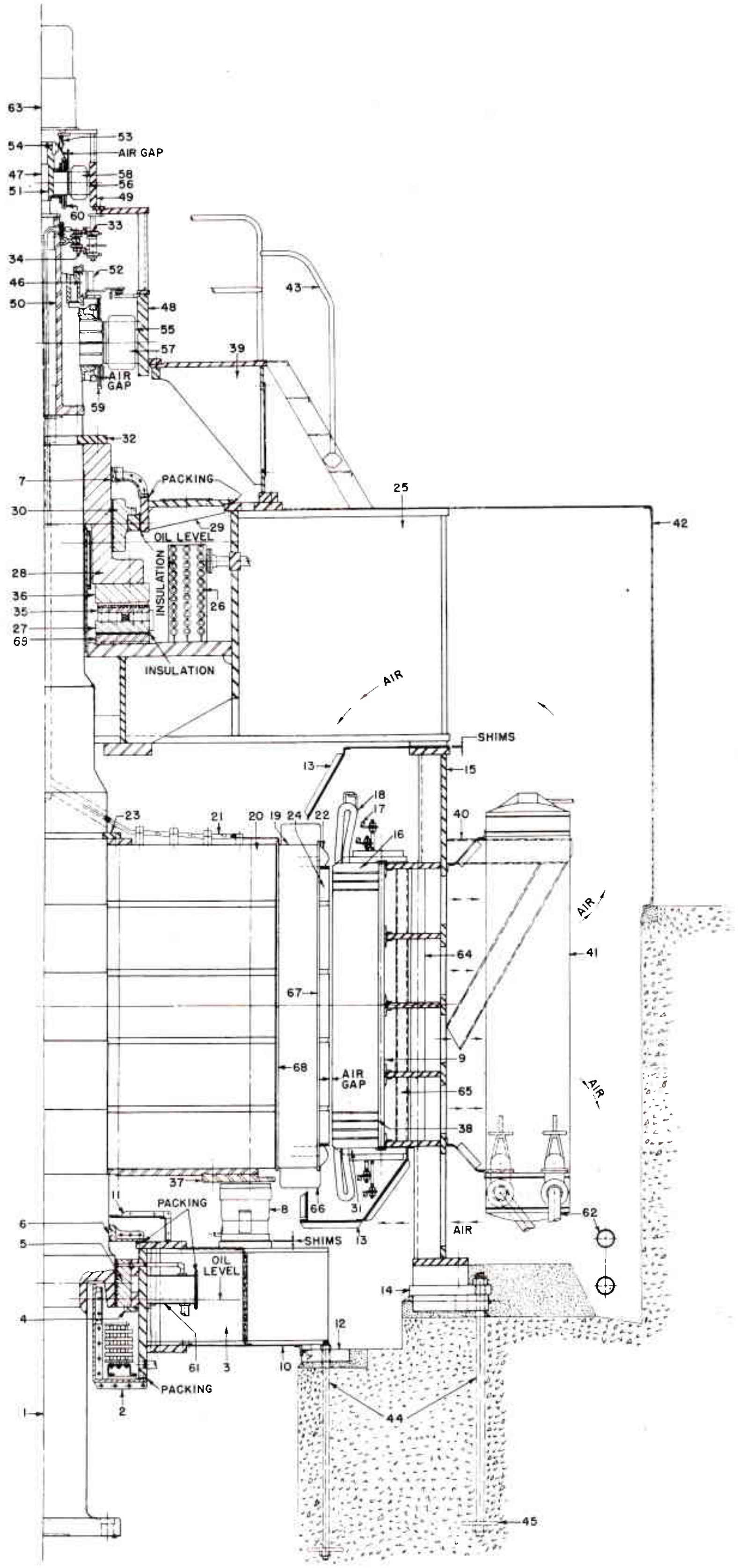


Fig. 2-3. A typical generator (40,000 kva and 333 rpm) with a combined guide and thrust bearing above the rotor.

NOMENCLATURE FOR FIG. 2-4

1. Shaft
2. Air-cooler piping
3. Lower oil pan
4. Guide-bearing adjusting screw
5. Lower bearing bracket
6. Cover plates
7. Lower-bracket foundation cap
8. Adjustable lower guide bearing
9. Oil deflector
10. Guide-bearing support
11. Lower rotor-spider center plate
12. Brake plate
13. Brake and jack
14. Fan
15. Lower air deflector
16. Stator frame
17. Stator foundation cap
18. Surface air cooler
19. Air-cooler support
20. Brake-plate support
21. Stator coil
22. Field leads
23. Upper rotor-spider center plate
24. Upper-bearing-bracket circular hub
25. Guide-bearing adjusting screw
26. Rotor-spider arm
27. Rotor coil
28. Upper air deflector
29. Rotor-pole end plate
30. Stator winding support (binding band)
31. Fire extinguisher piping
32. Circuit rings
33. Cover plates and housing
34. Upper oil pan
35. Guide-bearing support
36. Adjustable upper guide bearing
37. Thrust-bearing base plate
38. Thrust-bearing stationary segments
39. Thrust-bearing runner plate
40. Oil well tube
41. Thrust-bearing housing
42. Thrust-bearing spring cage
43. Thrust-bearing oil cooler
44. Oil drain
45. Oil deflector
46. Exciter support
47. Oil baffler
48. Thrust collar
49. Retaining ring
50. Exciter fan
51. Thrust-bearing springs
52. Main exciter rotor coil
53. Oil deflector
54. Thrust bearing base ring
55. Main-exciter rotor spider
56. Main-exciter commutator
57. Collector ring
58. Pilot-exciter shaft
59. Pilot-exciter rotor flange
60. Pilot-exciter rotor coil
61. Pilot-exciter rotor spider
62. Pilot-exciter commutator
63. Pilot-exciter brush rigging
64. Permanent magnet generator
65. Pilot-exciter brush-holder yoke
66. Pilot-exciter field coil
67. Pilot-exciter stator frame
68. Pilot-exciter field pole
69. Stator key bar
70. Collector brush rigging
71. Main-exciter brush rigging
72. Main-exciter brush-holder bracket
73. Main-exciter brush-holder yoke
74. Angle-iron spacer bar
75. Main-exciter field coil
76. Main-exciter stator frame
77. Main-exciter field pole
78. Stairway
79. Oil baffler
80. Stator core air duct
81. Stator core
82. Foundation bolts
83. Radial arm of upper bearing bracket
84. Tapered bolts
85. Rotor-hub bolts
86. Free laminated rim
87. Rim studs
88. Bottom insulating collar
89. Top insulating collar
90. Rotor key bar
91. Rim key
92. Dovetailed rotor pole

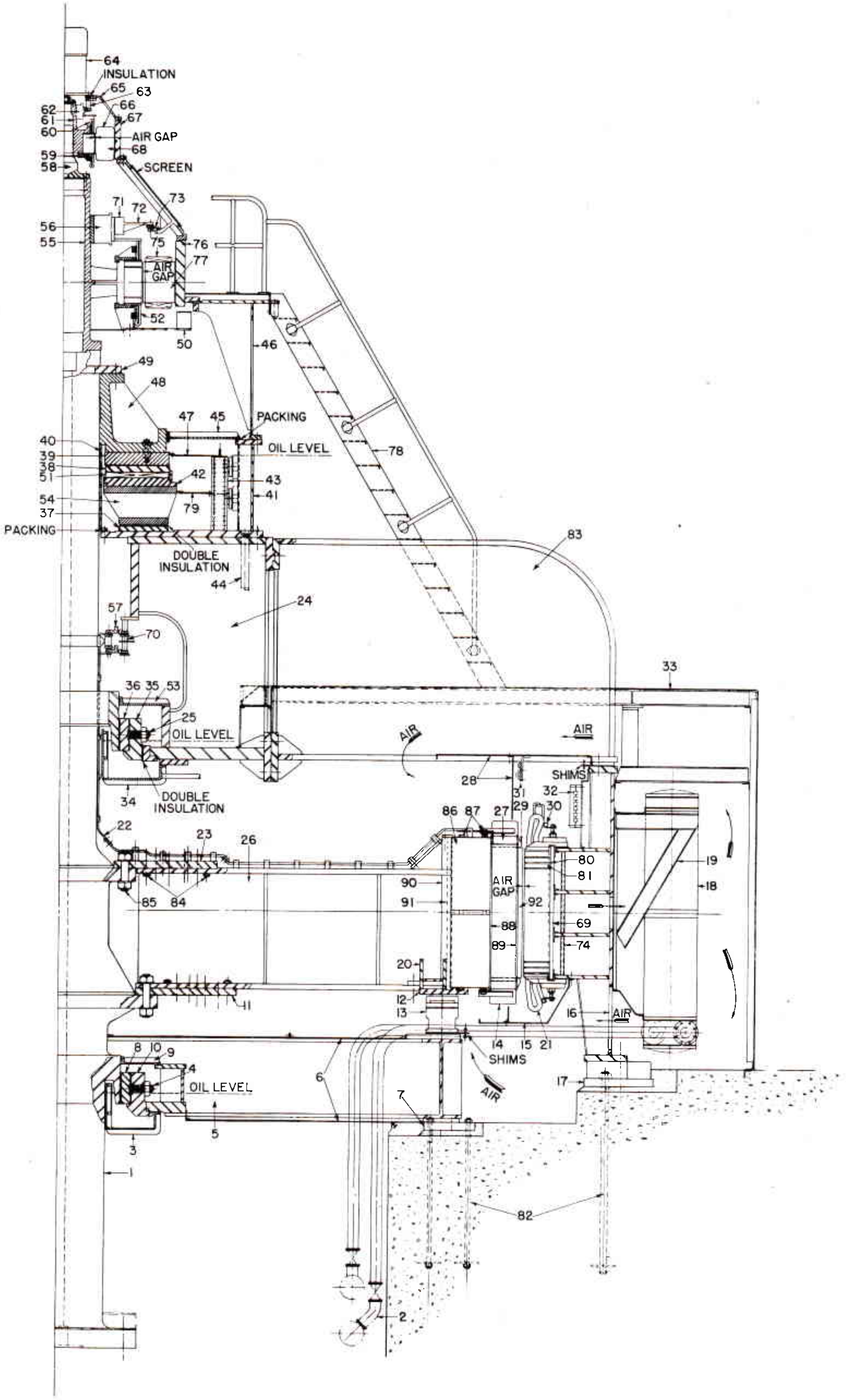


Fig. 2-4. A typical generator (45,000 kva and 95 rpm) with the thrust bearing above the rotor and a separate upper guide bearing.

NOMENCLATURE FOR FIG. 2-5

1. Shaft
2. Lower oil pan
3. Thrust-bearing spring cage
4. Adjustable lower guide bearing
5. Lower oil guard
6. Rotor-spider arm
7. Field leads
8. Upper oil pan
9. Adjustable upper guide bearing
10. Sleeve-type journal
11. Thrust-bearing base ring
12. Guide bearing support
13. Upper oil guard
14. Main-exciter rotor coil
15. Thrust-bearing stationary segment
16. Main-exciter rotor spider
17. Collector leads
18. Main-exciter commutator
19. Collector assembly
20. Pilot-exciter rotor coil
21. Thrust-bearing runner
22. Pilot-exciter shaft
23. Pilot-exciter rotor spider
24. Pilot-exciter commutator
25. Pilot-exciter brush rigging
26. Pilot-exciter brush-rigging support
27. Pilot-exciter stator frame
28. Pilot-exciter field coil
29. Pilot-exciter field pole
30. Pilot-exciter support
31. Exciter lighting
32. Collector brush rigging
33. Main-exciter brush rigging
34. Main-exciter field coil
35. Main-exciter stator frame
36. Main-exciter field pole
37. Exciter fan
38. Stairway and railing
39. Cover plates
40. Air housing
41. Surface air cooler
42. Stator frame
43. Circuit rings
44. Clamping finger
45. Stator coil
46. Air deflector
47. Fan
48. Rotor coil
49. Dovetailed rotor pole
50. Parallel-arm upper bearing bracket
51. Air cooler piping
52. Foundation bolt plate
53. Foundation bolt
54. Stator foundation cap
55. Lower air deflector
56. Brake and jack
57. Brake piping
58. Chock
59. Lower-bracket foundation cap
60. Foundation bolt
61. Bearing-housing cover plate
62. Cover plates
63. Vent pipe
64. Drawout-type bearing oil cooler
65. Parallel-beam lower bearing bracket
66. Oil baffler
67. Relief door
68. CO_2 fire extinguisher piping
69. Stator winding support (binding band)
70. Upper, rotor center plate
71. Lower, rotor center plate
72. Rotor-hub bolts
73. Tapered bolts
74. Rotor key bar
75. Rim stud
76. Free laminated rim
77. Stator core
78. Stator ventilating duct
79. Stator key bar
80. Brake plate

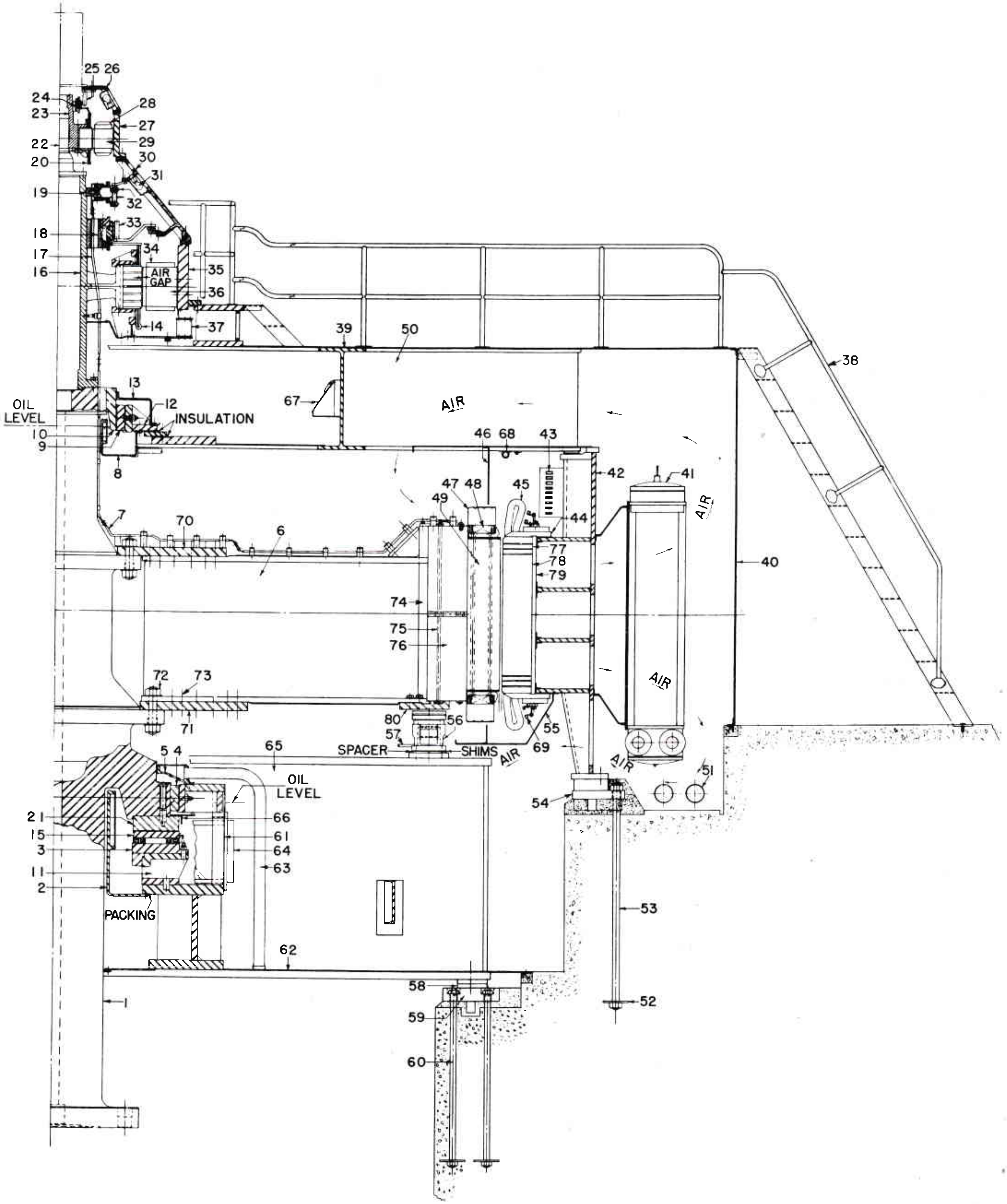


Fig. 2-5. A typical generator (50,000 kva and 106 rpm) with a combined guide and thrust bearing below the rotor.

COMPONENT PARTS

3-1 FOUNDATION CAPS

Foundation caps should be supported solidly on the foundation by means of flat plates and shims, sliding-parallels, or jack bolts. This blocking should be substantial enough to carry the total vertical loading without being grouted. Tapered wedges driven under the edges of the caps or other "temporary" types of blocking should not be used.

When the supported member rests directly on the foundation cap, the cap is usually attached to that member and located by the alignment of the supported member. The holding-down bolts should be centered in their holes to allow for final alignment (Cardboard sleeves provide a simple method of centering these bolts while locating the foundation caps). After **final** alignment of the stator, these caps should be grouted with sufficient space allowed for installing the radial dowels shown on the outline drawing.

When fitted chocks are used between the supported member and the foundation caps (or sole plates), the caps are usually set and grouted before placing the supported member. After the supported member is aligned (usually by means of jack-screws which bear against the foundation caps) the chocks are machined to fit.

3-2 STATOR FRAME

When the stator frame is shipped in several sections, place the sections on the foundation caps in approximately their final position and insert the joint bolts. Block under the foundation caps until the frame is at approximately the elevation shown on the outline drawing and level. Use the **top** of the frame as a reference for both leveling and elevation.

The sections should be aligned so that the cores match at the splits (particularly at the bottom of the slot). Each core joint should be in contact over at least 60 percent of its surface, and no point should be open more than 0.005 inch.

When the joints are aligned, remove one joint bolt at a time, heat it to 100 C in hot water or oil and replace it. Shrink the bolts nearest the core first.

After the joint bolts are tight, the joint dowels should be installed.

Large-diameter machines are furnished with push-pull jacks for adjusting the radial position and correcting possible radial distortion of the frame.

On larger machines, additional dowel holes must be drilled in the joint bars after the frame is in its final position.

After the frame is adjusted and the foundation caps grouted, radial dowel holes, as shown on the outline, should be drilled at the joint between the frame and foundation cap.

The stator frame should be grounded to protect personnel in case of an insulation failure. The ground connection should be heavy enough to prevent dangerous voltages from frame to ground when carrying the armature short-circuit current.

3-3 STATOR CORE

The core is generally compressed axially by clamping flanges or plates held by through-bolts.

The core is properly tightened during manufacture and should not require additional tightening. However, core tightness should be checked during installation. The core is properly tightened when the tightening torque is within the range of values given in Table 3-1.

TABLE 3-1

TORQUE TO BE APPLIED TO STATOR-CORE CLAMPING BOLTS

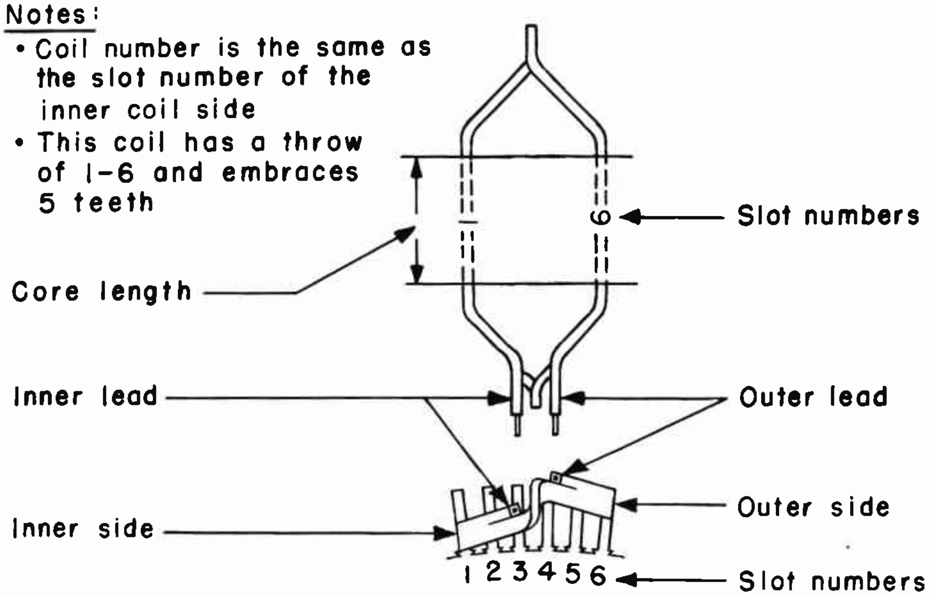
Diameter of Bolt or Stud (inches)	Tightening Torque (lb-ft)
1	150-175
1 1/4	300-355
1 1/2	500-600
1 3/4	810-970
2	1200-1440

The magnetic portions of alternating-current stators are composed of thin steel laminations carefully varnished to prevent excessive eddy currents. If punchings are damaged (smeared) to the extent that metal bridges the gap between laminations, local hot spots will develop. Unfortunately, the smeared areas do not tend to burn free, but rather tend to weld together. The heat from the hot spot affects the coil insulation and a winding failure may follow.

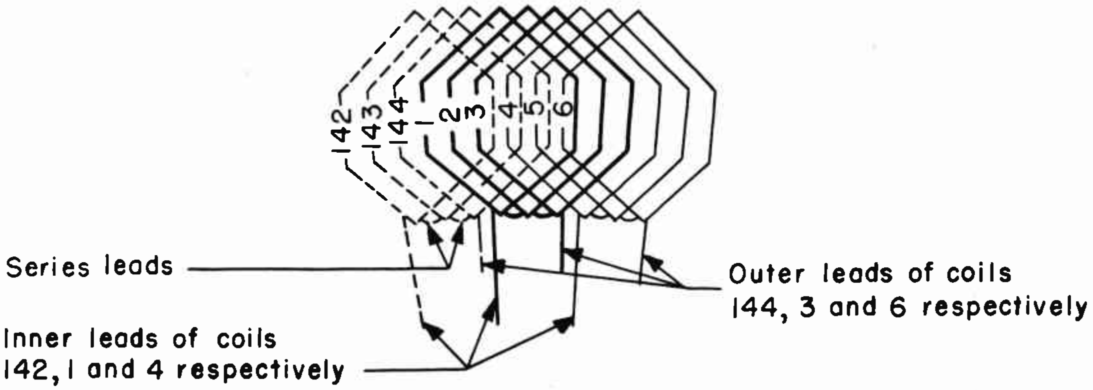
Every precaution should be exercised in handling and storing stators to prevent damage.

VIEW OF A TYPICAL COIL NUMBER ONE

Notes:
- Coil number is the same as the slot number of the inner coil side
- This coil has a throw of 1-6 and embraces 5 teeth



SCHEMATIC DIAGRAM OF 3 PHASE-GROUPS OF 3 COILS EACH



SIMPLIFIED DIAGRAM OF ABOVE 3 PHASE-GROUPS

Notes:
- Coil pitch is shown by the number of teeth that the coil embraces
- Light lines indicate phase 1
- Heavy lines indicate phase 2
- Dashed lines indicate phase 3

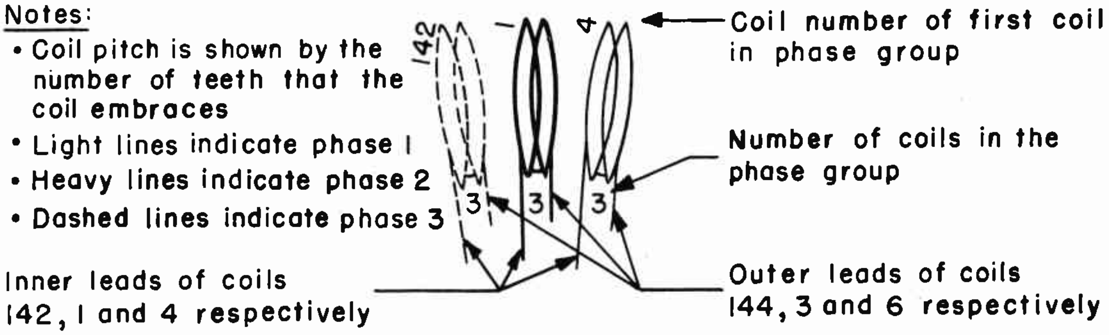

142
1
4
Coil number of first coil in phase group
Number of coils in the phase group
3
3
3
Inner leads of coils
142, 1 and 4 respectively
Outer leads of coils
144, 3 and 6 respectively

Fig. 3-1. Interpretation of the conventional stator-coil diagram.

A loose core may be detected by the buzzing noise which occurs when the machine is excited. Another evidence is the formation of rust around the fingers that are not tight. This rust is due to iron powder produced by vibration and becomes very noticeable after a time. The vibration may wear the enamel off the punchings and cause local hot spots to develop because of excessive eddy currents.

Smeared punchings or a loose core should be repaired only by experienced personnel. If the punchings are smeared or a loose core is discovered, contact the General Electric Company for further information.

3-4 STATOR WINDINGS

When the stator is shipped in more than one section, the stator-joint coils must be installed and connected during erection. Coils are designed for a snug fit widthwise in the slot and must be handled properly to prevent damage during installation.

If the coil insulation includes mica, the coils should be installed only by competent winders who are experienced with this type of insulation.

These coils must not be installed or disturbed and the insulated portion of their leads must not be bent when cold. Before such handling, they should be carefully heated to a temperature of 80 C by thermometer. Use a heating current which will bring the coil to this temperature in not less than 45 minutes. Too rapid heating will produce excessive internal temperatures and result in internal voids in the insulation.

3-5 STATOR LEADS AND CONNECTIONS

Connections should be made in accordance with the connection diagram furnished with the machine. Fig. 3-1 shows the interpretation of the conventional stator-coil diagram. Tables 3-2 and 3-3 show the number of tapings to be applied and the kinds of tape and varnish to be used. The joint insulation should overlap the existing insulation adjacent to the connection.

TABLE 3-2

INSULATION OF CLASS A ARMATURE JOINTS

Type of Joint	Pole lead Phase Lead Circuit ring Machine Terminal Binding Band	Series lead
Rated Voltage not over	Number of half-lapped tapings of G-E No. 992, 0.012 inch, bias, black-varnished-cambric tape—Brush G-E No. 457 varnish over each taping.	
1000	2	1
3000	2	2
5000	3	3
7000	4	3
9000	5	4
11000	6	5
13000	7	6
14000	8	7
Final Taping	Apply one, half-lapped taping of 0.005 inch, treated cotton tape, brushed with G-E No. 457 varnish.	None
Final Treatment	Spray finished joint with G-E No. 7815 Glyptal* varnish and allow to air dry thoroughly. Then spray with G-E No. 7144 Glyptal varnish and allow to air dry.	

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* Registered Trade-mark of General Electric Company.

TABLE 3-3

INSULATION OF CLASS B ARMATURE JOINTS

Type of Joint	Pole lead Phase lead Circuit ring Machine Terminal †Binding band	Series lead
Rated Voltage not over	Number of half-lapped tapings of G-E No. 77865, 0.010 inch, mica-mat tape — Brush G-E No. 457 varnish over each taping.	
1000	1	1
2000	2	1
4000	2	2
5000	3	2
7000	3	3
10000	4	4
12000	5	5
14000	6	5
16000	7	6
Final Taping	Apply one, half-lapped taping of 0.005 inch, glass tape saturated with G-E No. 457 varnish	
Final Treatment	Spray finished joint with G-E No. 7815 Glyptal varnish and allow to air dry thoroughly G-E No-1232 Then spray with G-E No. 7144 Glyptal varnish and allow to air dry.	

† Reinforce with 2 layers of 0.006 inch (G-E No. 1754) mica sheet before applying the first mica-mat tape and 2 layers before applying the glass tape.

On a vertical lead, start each layer of tape at the bottom of the joint and work upward, and do not support more than five feet of station cable on a machine terminal.

Higher voltages or unusual situations should be referred to the factory.

*3-6 INSULATION RESISTANCE

The insulation resistance of a winding varies with temperature, the moisture in or on the winding, cleanliness, age, and the value and duration of test voltage. When properly interpreted, insulation resistance readings, while not a definite measure of the insulation dielectric strength, afford a useful indication of the suitability of a winding for operation or over-potential test. To correlate periodic readings it is necessary that they be taken at a definite temperature, voltage, and length of time. The application of 500 volts d-c for one minute is recommended.

> **NOTE:** *The test voltage constitutes a voltage test and the value used should be selected accordingly, particularly for low-voltage or wet machines.*
>
> *The winding should be grounded prior to testing to remove any residual charge.*

The standard value of insulation resistance is the least value which a winding should have after cleaning and drying, or if an overpotential test is to be applied. The standard value is not necessarily the minimum value for operation of a machine. A dry winding will have a lower value of insulation resistance as it becomes dirty in operation. It is recognized that it is possible to operate machines with insulation resistance approximating 1/10 the standard value.

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* For more complete information, See Report No. 43 "Recommended Practice for Testing Insulation Resistance for Rotating Machines" (dated April 1950) published by American Institute of Electrical Engineers, 33 West 39th Street, New York City 18, New York.

Armature Windings of Machines Rated 1 to 999 KVA

The standard value of insulation resistance for armature windings of machines rated 1 to 999 KVA inclusive is:

$$R = E + 1$$

where R is the standard insulation resistance in megohms for winding temperatures up to 75 C.
E is the rated machine voltage (line-to-line) in kilovolts.

Armature Windings for Machines Rated 1000 KVA or More

The standard value of insulation resistance for armature windings rated 1000 KVA or more is:

1.3 7 0.12 13.3

$$R = K_T K_I S (E + 3.6)$$

where R is the standard value of insulation resistance in megohms.
K_T is the insulation-resistance-temperature factor from Fig. 3-3.
K_I is 2.5 for varnished cambric (Class A) insulation and 7.0 for mica (Class B) insulation.
S is the machine-size factor from Fig. 3-2.
E is the rated machine voltage (line-to-line) in kilovolts.

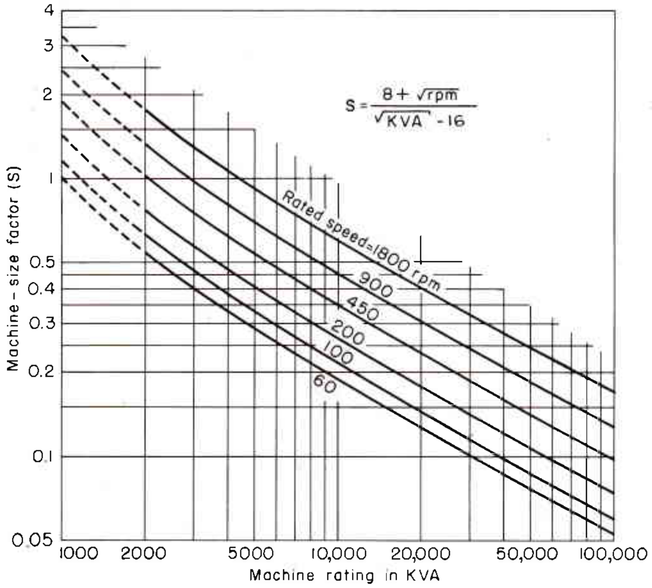

Fig. 3-2. A machine-size factor for use in determining the standard insulation resistance.

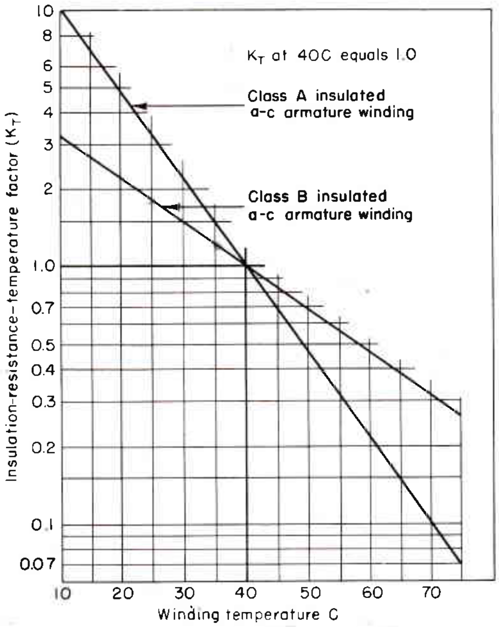

Fig. 3-3. Approximate insulation-resistance-temperature factor.

Field Windings

The standard value of insulation resistance for both Class A and Class B field windings should be of the order of one megohm for winding temperatures up to 75 C.

3-7 POLARIZATION INDEX

The polarization index is:

$$PI = \frac{R_{10}}{R_1}.$$

where PI is the polarization index.
R_{10} is the resistance after a 10 minute application of voltage.
R_1 is the resistance after a 1 minute application of voltage.

The polarization index (PI) is useful in determining when the drying process may be terminated or in determining the condition of windings on which no previous data are available. The PI of an a-c armature winding which is clean and dry is usually of the order of 1.5 or more for a Class A winding and 2.5 or more for a Class B winding. A typical curve showing variation in insulation resistance values during the drying period is shown in Fig. 3-4.

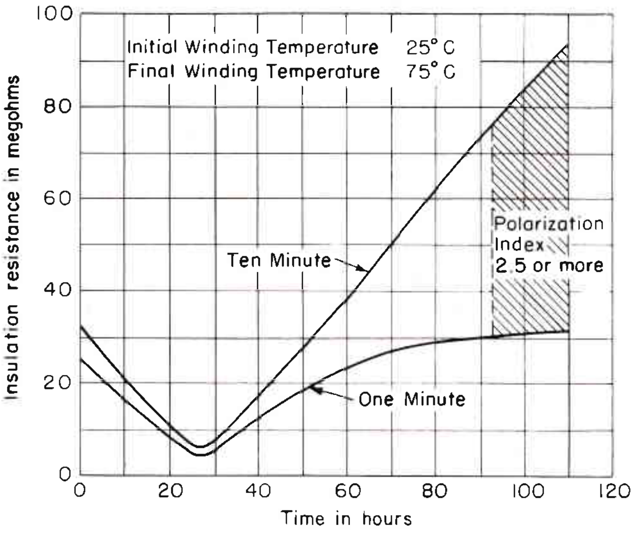

Fig. 3-4. Change in one-minute and ten-minute insulation resistance during the drying process of a 13,800-volt, Class-B-insulated, a-c armature winding.

3-8 DRYING-OUT WINDINGS

Moisture reduces the insulation resistance of a winding, and should be removed before an appreciable voltage is applied to the winding. Generally, if a machine has not been exposed to rain or unusual dampness, it will not require drying out. If drying is necessary, the following methods are recommended.

NOTE: *Regardless of the method used, the windings should not exceed a temperature of 90C measured by resistance or resistance-temperature-detector or 75 C measured by thermometer. The rate of heating should be controlled so that this temperature is attained in not less than two hours, and preferably in not less than six hours.*

Armature Windings

The short-circuit method of drying is applicable only to machines which can be mechanically driven. Operate the machine at rated speed with all phases of the armature winding short-circuited. Excite the field to give the armature short-circuit current necessary to heat the winding (usually between 60 to 100 percent of rated armature current — see note above).

The direct-current method of drying is applicable to all types of a-c machines and is performed with the machine stationary. A low-voltage, high-current source of d-c power (such as a welding generator) is necessary for drying-out armature windings. The armature terminals may be connected in series or multiple to best suit the source of power. It is better to have equal currents in all phases. However, on Y-connected machines with only three leads, it is necessary to connect two phases in parallel and in series with the third phase. The maximum current in any phase should be limited to that which is necessary to give the temperature-time relation noted above. Since the machine is stationary, this current will usually be between 25 and 50 percent of the rated value.

The external-heat method employs an oven or a number of coils of steam pipe enclosed in a box with the machine. Openings in the top and bottom of the box should be provided to give ventilation. The moisture is carried off by the hot air. The temperature should not exceed 85 C.

NOTE: *Drying should be continued until the insulation resistance attains a satisfactory value as described in Sect. 3-6.*

CAUTION: *Any drying operation is a fire hazard and due precautions against fire must be taken.*

Field Windings

The field windings may be dried by passing current through them or by placing them in an oven. Operation for a few days under load is an effective procedure for drying out the field winding. Do not use the brushes to carry current to the field windings with the rotor stationary because this may damage the collectors. Copper bands clamped around the collector rings may be used as connections.

Field windings which have been exposed to moisture sometimes get rust deposits in the creepage paths between the pole-body insulation and the top (next to the pole tip) collar. These deposits short out the ground insulation and must be removed. The coil and the top collar can be carefully lowered a couple of inches to clean these surfaces if necessary.

3-9 DIELECTRIC TESTING

No winding should be given a dielectric test before a complete visual inspection of the winding has been made and insulation resistance indicates the winding to be clean and dry. Tests for acceptance should be given as soon as possible after these conditions are met and before the machine has been in extended service.

CAUTION: *These tests should be applied only by experienced personnel, and adequate safety precautions must be taken.*

A-C Voltage Testing

The test voltage to be applied should be an a-c voltage of the RMS value specified below. It must come from a variable-voltage supply under stable control and be relatively free from harmonics. The actual test voltage must be measured by a proper potential transformer and voltmeter. A sphere gap should not be used to measure the test voltage because it may produce harmful surges when it arcs over.

The preferred testing equipment is a testing transformer designed specifically for high-potential testing, used within its rating, and supplied from a voltage known to be approximately sinusoidal.

A testing transformer which uses a third winding for potential measurements should **never** be used beyond its current rating because the voltage applied may be considerably greater than the voltage read.

If an ordinary transformer is used as a testing transformer or to supply a testing transformer, it should be operated below 90 percent rated voltage. This is to prevent introducing harmonics into the test voltage.

The test voltage must be measured directly by a separate potential transformer (not by means of the step-up-transformer primary voltage).

During the test, the voltage should be rapidly increased to the required level, held for one minute, and then rapidly reduced to zero.

NOTE: *Full voltage must not be applied or removed by closing or opening a switch.*

After the test, the tested winding should be discharged to ground before it is touched by personnel.

To apply a high-potential test, connect together all terminals of the section to be tested and apply the specified test voltage between those terminals and ground. All other windings, sections of windings and metal parts must be grounded. No leads are to be left unconnected during the test because this may cause a severe stress at some point in the winding.

The following a-c, high-potential-test voltages are the maximum, RMS, test voltages recommended for the service condition specified. They should not be exceeded unless other values have been accepted by contract specifications.

A new winding which has not previously been tested should be tested as shown in Table 3-4.

Machines which are received with windings completely assembled will have successfully passed the standard ASA test before shipment. If further tests are required before putting the machine in service, it is recommended the test voltage be 75 percent of the values in Table 3-4.

The recommended test voltages to be applied to a winding which has been in service are shown in Table 3-5.

The amount of charging KVA required to test a particular machine can be obtained by writing to the General Electric Company. The approximate amount of charging KVA for a three-phase armature is given by the formula:

$$KVA_{CH} = \frac{K_A\,K_B\,L_C\,f\,E_T^2}{E + 3.6}$$

where KVA_{CH} is the charging KVA required to test all three phases simultaneously. (Approximately 40 percent of this KVA is required to test one phase with the other two grounded).

K_A is 0.015 for varnished cambric (Class A) insulation and 0.025 for mica (Class B) insulation.

K_B is the machine-size factor from Fig. 3-5.

L_C is the loss coefficient from Fig. 3-6.

f is the test frequency in cycles per second.

E_T is the test voltage in kilovolts.

E is the rated, machine voltage (line-to-line) in kilovolts.

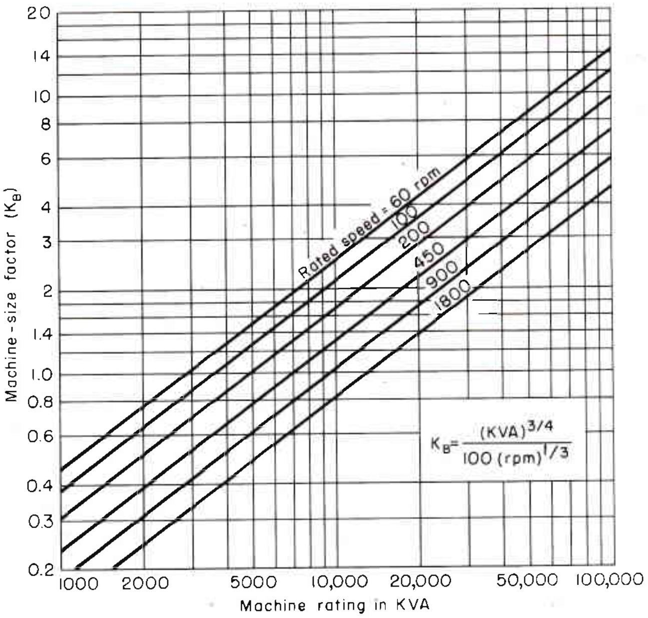

Fig. 3-5. Approximate machine-size factor for use in determining the charging kva for a high-potential test.

TABLE 3-4

TEST VOLTAGES FOR NEW WINDINGS
(E = rated, rms or d-c, line-to-line voltage)

WINDING	A-C (RMS) TEST VOLTAGE	DC
ARMATURE		
New coils after they are assembled, but before they are inter-connected.	**2 1/5 E + 2000 volts**	3.5 E + 3200
New coils which have been disturbed when installing the stator-joint coils on a new machine	**2 1/5 E + 2000 volts**	3.5 E + 3200
After all winding is completed	**2 E + 1000 volts**	3.2 E + 1600
GENERATOR FIELD	**10 E, but not less than 1500 volts**	
MOTOR FIELD	**2500 volts**	

TABLE 3-5

TEST VOLTAGES FOR WINDINGS IN SERVICE
(E = rated, rms or d-c, line-to-line voltage)

WINDING	A-C (RMS) TEST VOLTAGE	
***ARMATURE**		2.13
Before installation of a partial set of coils	**1 1/3 E + 600 volts**	2.16 E + 960
After installation of a partial set of coils	**1 1/4 E + 500 volts**	2 E + 800
To demonstrate suitability for continued service	**1 1/5 E + 400 volts**	1.92 E + 640
****FIELD**		
125-volt generator field	**1000 volts**	
250-volt generator field	**1500 volts**	
Any motor field	**1500 volts**	

* For large, Class-B, armature windings, some users prefer a test voltage that is 10 percent higher than the one shown.
** For some large machines, or special machines, the test voltage may be somewhat higher than the one shown.

D-C Voltage Testing

Proper application of d-c voltage should give a reasonably satisfactory over-potential test. However, an a-c voltage test is recommended because it more nearly duplicates the operating voltage distribution and stress in the windings.

The d-c voltage test should be made only by operators experienced in this type of testing. Because of the difference in voltage distribution, the d-c test may subject portions of the winding to an abnormal overvoltage. The ratio of d-c to a-c voltage for equal voltage stress will vary depending upon the part of the winding involved and the condition of the insulation and creepage paths. It should be recognized that an improperly applied d-c test may subject the

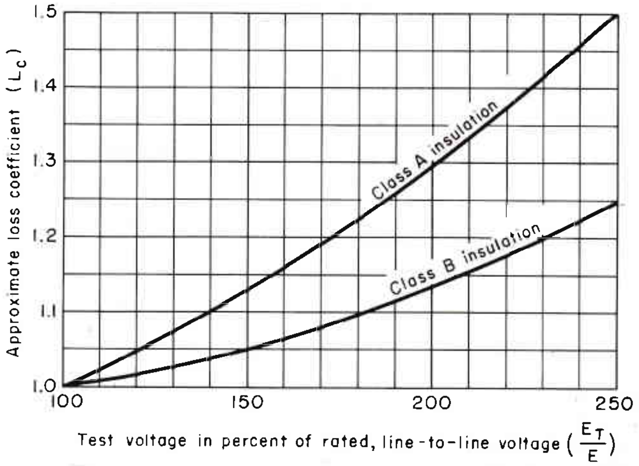

Fig. 3-6. Approximate loss coefficient for use in determining the charging kva for a high-potential test.

winding to an unusual voltage stress which may result in a premature winding failure either during the test or during subsequent operation.

A ratio of d-c to rms, a-c, test voltage of 1.6 is recommended when substituting a d-c test for an a-c test on a new winding. D-c, over-potential testing is not recommended for new windings rated less than 6000 volts line-to-line.

The d-c voltage should be applied only to a completely discharged winding and should be applied in steps. The voltage at each step should be held until the charging current decays to approximately zero and only the leakage current remains. It is desirable to record the leakage current at several values of voltage and plot a curve of leakage current versus voltage for each test.

The winding must not be discharged by abruptly grounding it or by applying a reversed d-c voltage. It should be discharged by gradually reducing the power-supply voltage to approximately half value and then discharging the winding to ground through a resistance of 25,000 to 100,000 ohms. After it is discharged, the winding should be solidly grounded and left for several hours before it is considered completely discharged or before a reversed-polarity voltage is applied.

When a d-c voltage test is used to determine the condition of a winding which has been in service, the recommended, maximum, d-c, test voltage is less than 1.6 times the a-c test value given in Table 3-5. A sharp increase in leakage current may be an indication of impending failure or flashover and the test should be stopped at this point regardless of the voltage attained.

If there is any question concerning the application of a d-c voltage test in a particular case, the Engineering Section, Large Motor and Generator Department, General Electric Company, Schnectady, New York, should be consulted.

CAUTION: *The d-c voltage test requires additional safety precautions because of the high-voltage charge retained in the insulation after the test. The absorbed charge, which is retained in the winding after a d-c voltage has been applied, discharges very slowly. This may cause a dangerous voltage build up if the ground connection is removed after the winding has once been grounded. It is advisable, therefore, to ground the winding for at least a day after the last d-c voltage test before anyone is allowed to touch it. Because of the surface charge that may be retained on the insulation or an ungrounded metal part, no one should be allowed to touch any ungrounded metal or insulation until several hours have elapsed after the test voltage has been removed.*

3-10 SHAFT

Plumb-wire checks should be made to check the straightness and plumbness of the assembly of shafts. The shaft assembly should be considered straight when no point (correlated for diameter variations) deviates more than 0.003 inches from a straight line joining the top and bottom points. The shaft assembly should be considered plumb when the top and bottom points do not deviate from plumb by more than ¼-mil per foot of shaft length. Certain points, as shown on the drawings, will be specially prepared and used for shop indicator readings. The plumb-wire checks should be taken at these points.

3-11 COUPLINGS AND COUPLING BOLTS

Before the couplings are pulled together, the mating surfaces must be parallel, clean, and free from burrs.

The smaller couplings may be pulled together by means of temporary bolts. The larger couplings may be pulled together using jacks and strong-backs which are supported by long temporary bolts. All couplings should be drawn up evenly to prevent distortion.

After the coupling faces have been pulled together, the bolt holes should be reamed or rebored to fit the permanent bolts (unless this has already been done in the factory).

The permanent bolts must be tightened **evenly** in accordance with factory instructions. **In the absence of specific instructions** on the desired amount of stretch, use the following:

$$\text{Stretch in inches} = \frac{L}{4000}$$

where L is the length of bolt between nuts in inches.

See Sec. 3-29 for additional information on bolting.

3-12 SHRINKING A ROTOR SPIDER OR A FLYWHEEL ON A SHAFT

Because of the danger of distorting the shaft, the shrinking of a rotor spider or flywheel on a shaft should be done at the factory so that the completed assembly can be checked in a lathe (and straightened if necessary).

If factory assembly is not possible, the following suggestions will help to reduce the hazards of field assembly (when the following discussion refers to rotor, it can be assumed to apply equally well to a rotor spider, hub, or flywheel):

The bore and the shaft should be carefully checked against each other with both at the same temperature. If there is any question about the fit the correct allowances should be obtained from the Engineering Section, Large Motor and Generator Department, General Electric Company, Schenectady, New York. The shaft and the bore should also be checked for burrs or other obstructions.

Any difficulty in assembling parts for a shrink fit can usually be traced to small defects in the key or keyways. Therefore, the key and keyways should be checked very carefully. All burrs and sharp corners should be removed and the key should be checked for width and height against both keyways. Both keyways should be checked for straightness and parallelism (if the keyways are not straight and parallel, the key acts as a wedge to prevent complete assembly of the two parts).

It is desirable to lubricate the keys and keyways with a mixture of graphite and machine oil before assembling for a shrink fit (vegetable or animal oil or white lead should not be used because they may start corrosion).

The shaft should be vertical when the rotor is shrunk onto it. This is to minimize the shaft distortion due to uneven cooling. (If the shrinking must be done with the shaft horizontal, the rotor should be turned as it cools to obtain more even cooling).

If the rotor consists of more than one axial section, the sections should be shrunk on one at a time. The dovetail slots in the rotor surface must be correctly aligned so that the poles can be assembled. To maintain this alignment, several aligning bars should be used in the dovetail slots while assembling and shrinking the rotor sections. The key used with this type of rotor consists of one larger segment, which fits the shaft keyway, and two, smaller, wedge-shaped segments for each rotor section. The larger segment is placed in position in the shaft keyway before the first rotor section is assembled. After each rotor section is shrunk onto the shaft, the two, wedge-shaped segments are fitted and driven into position in the rotor keyway.

The rotor should be heated in an oven (or temporary enclosure) by electric heaters or steam coils. The heating should be done slowly and evenly to prevent distortion. The oven temperature should not exceed 100 C for a rotor with its windings installed or 250 C for a rotor without windings. Therefore, it is desirable to perform the shrinking operation before the poles are assembled.

In order to allow time to correctly locate the rotor on the shaft, a diametral clearance of 1 mil per inch of shaft diameter should be obtained before the parts are brought together. This would require a temperature difference of approximately 132 C for assembling an interference fit of ½ mil per inch of diameter (the bore will expand 1 mil per inch for an 88 C change in temperature). To determine that the correct clearance has been obtained, the hot-rotor bore should be measured with a micrometer or pin gage which is at the same temperature as the shaft.

While the rotor is cooling, air should be blown against the side which is next to the shaft shoulder so that rotor will seize on this side first and not pull away from the shoulder as it cools.

> **NOTE:** *There is always some danger of the rotor getting stuck and seizing before it reaches the proper location against the shoulder on the shaft. Therefore, arrangements should be made beforehand for quickly disassembling the parts in case they do not go together quickly and smoothly. It is also desirable to make a trial lift beforehand with the rotor cold to check slings, clearances, etc. (sometimes the position of the crane is marked to facilitate getting it correctly placed over the shaft quickly).*

3-13 ROTOR-SPIDER ASSEMBLY

One type of spider is made up of plates and arms which are shipped disassembled. To assemble this type, the lower center-plate is placed on the shaft or erection pedestal, carefully leveled (the shaft should be plumbed at this time if the spider is being assembled on the shaft), and fastened by means of temporary bolts. The arms, upper center-plate, brake-plate supports, and brake plates are assembled on the lower center-plate. After the brake-plate supports and the brake plates are tightened, the tapered bolts in the center plates are tightened.

3-14 LAMINATED-RIM ASSEMBLY

If the thrust bearing is above the rotor, the rotor and shaft are usually handled as a unit. In this case provision should be made to support the shaft at the coupling so that it stands upright. If the rotor is to be handled apart from the shaft, steel blocking (or an erection pedestal) should be provided to support the rotor at the center. In either case, the central support should be capable of carrying the completed assembly. The height should be such that the bottom of the spider is about three feet from the floor. The floor at the ends of the arms must be able to support half the weight of the rim and poles.

The rotor, with the brake plates bolted to the rotor arms, should be leveled. Blocking for supporting the outer side of the rim punchings should be installed level with the top of the brake plate. Substantial blocking should also be used under the ends of the rotor arms and under the brake plates so that there will be no shifting as the laminations are stacked. The rotor and blocking should be re-leveled very carefully with a wye-level and micrometer target. Checks should be made after each pressing to insure that the rim is being assembled in a horizontal plane at right angles to the axis of the shaft.

In order to prevent a serious unbalance of the rotor due to variations in lamination weight and thickness, the laminations should be sorted by weight. The weight of the laminations in one pile should not vary more than ½ lb. Each pile is then used to assemble a complete ring around the rotor.

If the laminations have been sorted in the factory, care should be taken not to mix the punchings when unpacking.

The outer keys should be placed in the slots in the ends of the rotor arms and blocked out far enough so that there is room for inserting the inner (driving) keys after the stacking is completed. There should be enough clearance between the face of these keys and the bottom of the keyway in the rim laminations so that the punchings can be assembled easily over the keys. Temporary shims should be placed between the ends of the rotor arms and the inside of the rim punchings to center the rim on the rotor accurately.

Sufficient laminations are stacked on assembly pins to support the studs in a vertical position. The studs are then dropped into position in place of the assembly pins and the rest of the rim assembled by dropping the punchings over the studs.

Each layer of laminations should be seated on the previous layer by tapping with a heavy mallet. The laminations should be pressed at intervals of 12 to 16 inches as the rim is assembled.

After the rim stacking is completed, the brake plates are removed and the inner rim keys installed but not tightened. The nuts on the studs are then tightened and tack welded to the punchings. The studs should be tightened to the torques given in Table 3-6. Drive the rim keys evenly to prevent distortion of the rim. Maintain approximately uniform clearance between the ends of the rotor arms and the inside of the rim punching. Maintain concentricity of the outside of the rim with respect to the shaft. Rim keys may be redriven at intervals of about eight hours until tight, but should not be driven so far as to distort the rim.

3-15 ASSEMBLY OF RIMS HAVING SHRINK LINKS

A pin gage should be made whose length is longer (by two or three mils per inch of length) than the distance between the shoulders of the key (shrink link) when cold. The keys will expand approximately one mil per inch for each 88 C rise. Before heating the keys, the two sections of the rim should be brought metal to metal with temporary bolts or clamps and lined up properly. The keys should then be heated slowly and uniformly until the gage will move freely between the shoulders. The gage should be kept lying on the rim when not actually in use. This will insure that the gage is at the same temperature as the rim, and will avoid any errors caused by expansion of the gage from heating.

The keys must not be heated over 350 C.

The lower surface of the rim is often used as a braking surface. It is preferable, therefore, that the keys be flush at the bottom of the rim. The links expand in all directions when heated and should be dropped through the rim far enough to compensate for this expansion. Fig. 3-7 shows the scheme to accomplish this. A bar is supported on jacks under the two halves of the rim at the split. A 0.014 inch shim is placed between the bar and the bottom of the rim. The first section of the key will rest on the bar and be 0.014 inch below the rim surface. Experience indicated that this will bring the key practically flush when it has cooled.

TABLE 3-6

TORQUE TO BE APPLIED TO RIM STUDS

Stud Diameter (inches)	Torque (lb.-ft.)
1 1/4	450
1 1/2	750
1 3/4	1200

NOTE: *If for any reason a shrink link projects below the braking surface after cooling, it must be ground off flush and smooth.*

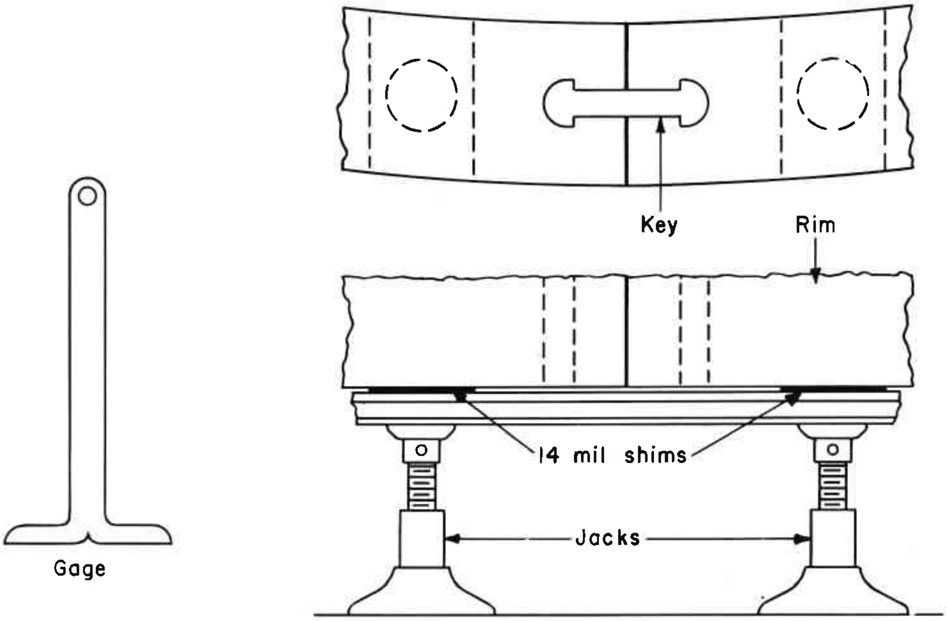

Fig. 3-7. Fitting rotor shrink links.

3-16 BOLTING SPIDER TO SHAFT

On large machines, the rotor-spider center-plates are bolted to flanges which are forged integral with the shaft. The bolt holes are sometimes left undersize and must be rebored together during installation. The lower center-plate will be centered on the shaft by a machined fit. There is usually a slight clearance between the upper center-plate and the shaft. It is essential that this plate be centered relative to the shaft. The shaft must be plumb and the spider level (using the brake plates as a reference) before the bolt holes are rebored. The boring must be done carefully so that the bolts will fit snugly.

3-17 FIELD-POLE ASSEMBLY

All poles must be located so that the centers of the poles (usually shown by a prick-punch mark) are all in the same plane. This plane must be at right angles to the shaft. Moreover, the center of the assembled poles should line up as nearly as possible with the center of the stator core. These conditions can be obtained by measuring from a machined surface on the shaft such as a shoulder or flange.

Use either a tram mounted on the shaft or a wye level to locate the centers. Do not use a brake plate or the end of the rotor as a reference point because these parts may vary considerably. After the level of the pole has been established, a stop block should be fastened in the keyway at the bottom of each pole. This is to prevent the pole from slipping down in case the keys become loose.

It is important that iron-to-iron contact is obtained between the pole core and spider for the full length of the pole base. Otherwise, the pole may loosen after a short period of operation and cause fatigue failure of the pole fastening.

Before the poles are installed, the spider surface and the base of the pole should be cleaned and deburred.

When the poles are attached by means of dovetails, the bearing surface of the dovetails and the spider slots should also be cleaned and de-burred. Particular attention should be given to the radius of the corners. The pole keys must have the corners relieved to match the dovetails. The corners of the keys may require filing to obtain proper relief.

Before the poles are installed, each pole should be checked visually to be sure the collar does not extend beyond the base of the pole. Questionable poles can be installed without the bottom collar and a measurement taken to the top of the pole from the shaft or rim surface. The pole is then removed and re-installed with the collars in place and this measurement duplicated. Another method for checking questionable poles is to fully tighten the pole and then heat the coil by passing current through it. If it is loose, it can be tightened further after it has cooled. A loose pole must be removed and filler removed or the bottom collar trimmed until it seats firmly. The amount of excess pole key after driving is an indication of the tightness of the pole. It should be approximately the same for all poles on one machine.

Poles which are held in place by radial bolts or studs (bolted poles) should be checked for tightness before the initial start and again after the machine has been run a short time. The torque required for proper tightening of pole bolts is given in Table 3-7.

Dovetail poles, which are held in place by tapered keys, must be carefully assembled. It is recommended that the keys be repeatedly re-driven at eight (or more) hour intervals until no additional movement of the keys is possible. Ordinarily, two or three drivings will insure that the keys stay tight. The inner key (i.e. the key nearest the shaft) should be the one driven and the one pulled when removing a pole. An exception to this is the case of a cast or forged rotor where the outer keys should be driven.

TABLE 3-7

BOLT-TIGHTENING TORQUES FOR BOLTED POLES

Bolt Diameter (in.)	Torque (lb.-ft.)
1/2	17 - 26
5/8	35 - 53
3/4	60 - 90
7/8	100 - 150
1	150 - 225
1 1/4	300 - 450
1 1/2	500 - 750
1 3/4	800 - 1200
2	1200 - 1800

Keys should be coated with powdered graphite mixed with pure mineral oil (Gredag No. 81½ is excellent) before being driven. White lead or lard oil should never be used on keys. These compounds may turn acid with age and cause rusting. After the keys are tight, the excess length should be cut off and the locking plates installed over the dovetail slots.

After the poles are installed, the field winding should be checked for correct polarity, uniformity of field-coil impedance, grounds, open-circuits, and high-resistance joints.

Before removing a pole or balance weight see Sect. 4-5 on balancing.

3-18 BEARINGS

Cleanliness and careful workmanship cannot be over-stressed in working with a bearing or any surface exposed to the lubricating oil. A bearing can easily be ruined by very little lint or dirt.

Any rags used around a bearing or bearing housing should be lint free (never use cotton waste). Excellent, lint-free paper towels are available commercially.

Before any bearing is operated, all piping and the housing must be carefully flushed and filled with filtered oil.

As soon as possible after assembly of a bearing, the bearing housing should be filled with clean lubricating oil to protect the bearing. However, if appreciable time elapses between installation and start-up, the oil should be removed and the housing flushed and refilled shortly before the machine is operated.

All oil should be passed through a filter located directly at the bearing housing. It is necessary to assure absolute cleanliness of the housing, and this may require that the housing be drained and filled several times. After the housing has been filled with oil, the rotor should not be raised, but should remain on the thrust bearing until the machine is started for the first time. This is to prevent the Gredag from being washed off the running surfaces.

3-19 THRUST BEARING

The thrust bearing consists of: A rotating plate (runner) which is rigidly attached to the shaft or the thrust collar; a set of relatively thin and flexible, babbitted, stationary segments; and a flexible support consisting of a number of precompressed springs.

The runner is made from fine-grained, hard, cast iron or steel and has no grooves. When desirable for convenience in assembly, it is made in two pieces.

The stationary member consists of a group of steel-backed, babbitted segments which are flexibly supported on precompressed springs. See Fig. 3-8. The oil is picked up by the runner in the spaces between segments. It is then drawn between the bearing surfaces to form a wedge-shaped, oil film on which the runner floats.

The bearing surface of the runner is carefully machined and polished at the factory to obtain a flat, smooth surface. The stationary, babbitted segments are machined to a uniform thickness. Because both rotating and stationary members have parallel surfaces, and because of the uniform support of the stationary segments, the G-E thrust bearing is to be put into service without fitting or scraping.

All steel or iron bearing surfaces are shipped from the factory with a protective coating to prevent rust.

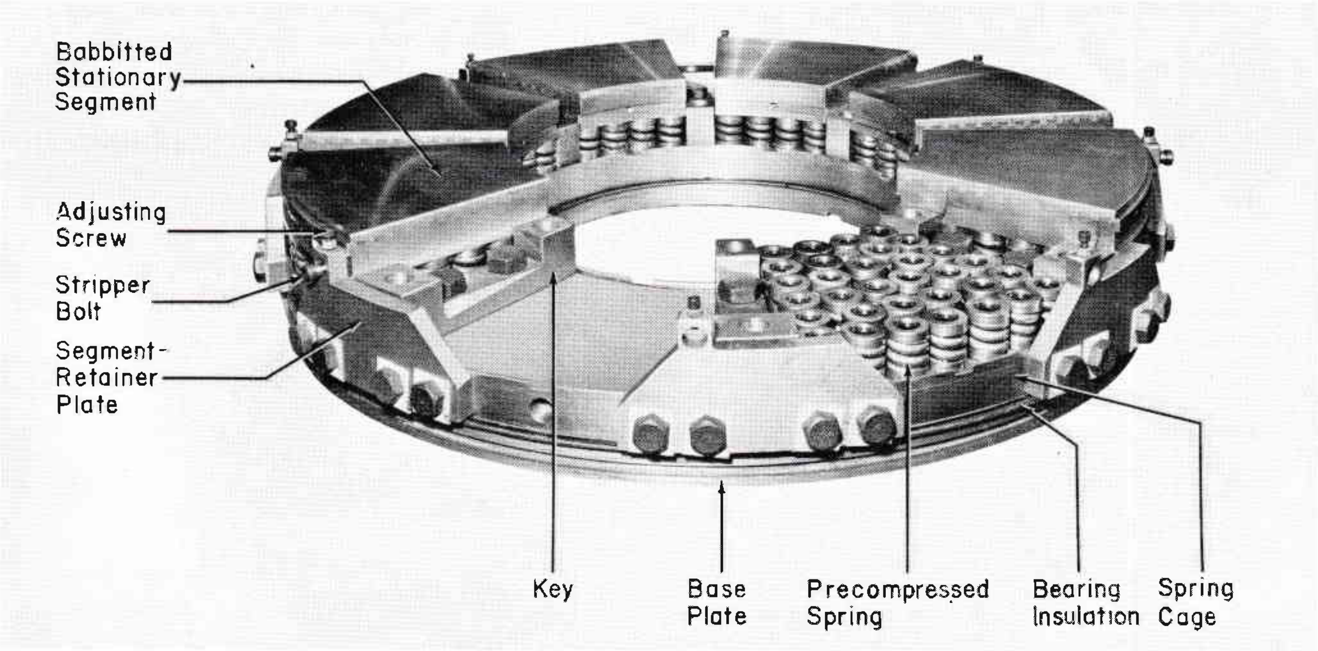

Fig. 3-8. The stationary element of a typical G-E thrust bearing with two segments and one group of springs removed.

The runner is packed in a special manner to prevent the protective coating from being rubbed off and the polished bearing surface from being scratched. The protective coating on the bearing surface can be easily dissolved with kerosene or a solvent containing some oil, and removed with clean rags (not cotton waste) or paint brushes having natural bristles. Brushes with synthetic bristles must not be used because they will scratch highly polished surfaces.

> **CAUTION:** *Read the discussion in Sec. 6-4 before using any cleaning solvent.*

Before and during assembly, all parts of the bearing and the bearing housing should be inspected to insure absolute freedom from dirt, lint, or other foreign matter.

Thrust Bearing Assembly

If a base ring is used, it is installed in the bearing bracket.

With the spring cage outside the bearing housing, the springs are assembled in the spring cage and the babbitted segments are placed on the springs. The segments should be positioned as far as possible outward (i.e. against retainer plates) and in the direction of rotation (i.e. against the radial keys). This is to make sure that the segments do not overhang the inner edge of the runner and that they will not shift when the machine is running.

This assembly is then placed on the base ring and the aligning dowels installed. The stripper adjusting screws should not be installed until after the runner is in place, because they extend above the stationary segments and would damage the highly-polished runner surface if bumped during installation of the runner.

Before installing the rotating plate (runner), the rubbing surfaces of both rotating and stationary members should be carefully inspected to assure freedom from scratches. Then, the rubbing surfaces of the stationary segments and the runner should be covered with Gredag No. 81½, which is supplied with the machine, or with a thick mixture of heavy lubricating oil and fine flake graphite. Take great care that no lint, dirt, etc. get into this coating. It is advisable to coat these surfaces immediately before they are brought together.

After the bearing is assembled, if the machine has strippers the adjusting screws in the segment-retainer plates should be installed and set to give 1/32 inch clearance between them and the stripper bolts in the bearing segments. The clearance between the stripper bolts and the lower side of the holes through the segment-retainer plates should be at least 3/16 inch, to be sure that the bolts will not make contact when the bearing is loaded.

The bearing-temperature-device bulbs should be installed, fastened in place, and the leads or tubes brought out so that they clear the runner and do not short circuit the bearing insulation. The leads or tubes should be well supported to prevent movement due to rotation of the oil.

NOTE: *There have been cases where the customer has requested that the rotor be rotated to check shaft alignment. This rotation may damage the thrust bearing and should not be performed without Large Motor and Generator Engineering approval.*

Thrust Bearing Above The Rotor

When the thrust bearing is above the rotor, the bearing parts are assembled by lowering them over the shaft. After the runner has been lowered onto the segments, the thrust collar is lowered to a position slightly above the runner. The runner can then be easily aligned with the vertical dowel holes in the thrust collar and the thrust collar lowered into position on the runner.

With the thrust collar in position, the thrust-collar retaining-ring may be installed and the rotor lowered onto the thrust bearing. This split retaining ring must be of uniform thickness or the thrust collar face will not be at a true right angle with the axis of the shaft.

All thrust-bearing, circular retaining rings should be checked for thickness with a micrometer before assembly. Any thickness variations exceeding 0.0005 inch should be corrected. As shown in Fig. 3-9, only that portion of the retaining ring which engages the shaft keyway need be checked for thickness.

Thrust Bearing Below The Rotor

When the thrust bearing is located below the rotor, the spring cage and the runner are split to facilitate their installation and removal without removing the rotor.

With the sections of the spring cage supported just outside the bearing housing (on opposite sides of the machine) the babbitted segments are cleaned, inspected for scratches, and placed in position on the nest of springs. The rubbing surfaces are then covered with Gredag No. 81½. The runner sections are cleaned and inspected for scratches. The rubbing surface is coated with Gredag No. 81½, and the runner is placed in position on top of the segments.

These assembled sections are moved horizontally into position in the housing, the spring cage is fastened to the base ring, and the sections of the runner are bolted together. The runner is then rotated to line up with the vertical dowel holes in the thrust block, and the shaft (or rotor) is lowered on to the bearing.

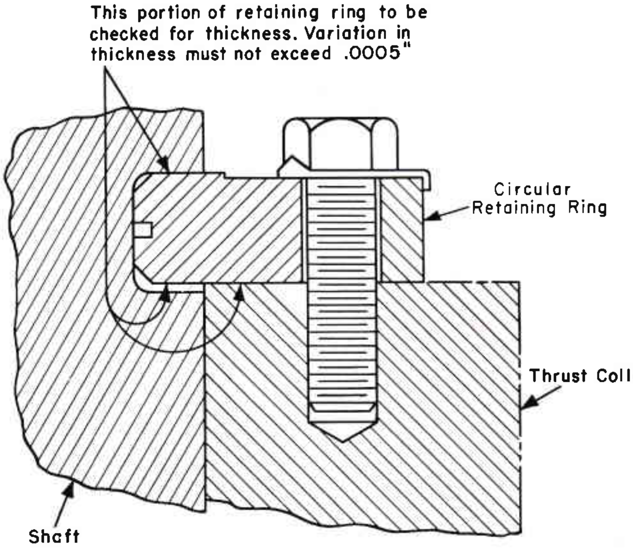
This portion of retaining ring to be checked for thickness. Variation in thickness must not exceed .0005"
Circular Retaining Ring
Thrust Collar
Shaft

Fig. 3-9. Checking thrust-collar circular-retaining-ring thickness.

The shaft, lower bracket, and thrust bearing are usually assembled as a unit and then placed in position inside the stator.

3-20 GUIDE BEARINGS

Most guide bearings are self-oiled and are designed to pump oil to the upper portion when the lower portion is immersed in oil. Ordinarily, unless otherwise specified, these bearings are designed for only one direction of rotation and will not be lubricated satisfactorily with reversed rotation.

Sleeve-type bearings may be either solid or split, but are not adjustable. If the bearing clearances differ appreciably from those shown on the assembly drawing, the bearing should be returned to the factory for re-fitting. If it is necessary to scrape a bearing in the field, it should be scraped only by someone with considerable experience in installing bearings. If there is any question, consult Large Motor and Generator Engineering before doing any scraping.

Segmental bearings are made up of independently adjustable segments and should be set to the clearance shown on the assembly drawing.

If the assembly drawing is not available, the radial clearances shown in Table 3-8 may be used.

The elevation of a self-oiled guide bearing must be such that the oil groove is completely covered by the opposite member. With sleeve-type bearings, the oilfeed hole must not be plugged. If the jacks are designed to lift the rotor more than half the width of the guide bearing, the elevation of the bearing must be such that the bottom of the journal will be below the center of the guide bearing when the rotor is in the maximum upward position.

TABLE 3-8

*CLEARANCES FOR VERTICAL GUIDE BEARINGS

Nominal Journal Diameter in Inches	Radial Clearance in Inches
4	.003 - .004
5 - 9	.003 - .005
10 - 15	.003 - .006
16 - 20	.004 - .007
21 - 24	.005 - .008
25 - 29	.005 - .009
30 - 34	.006 - .009
35 - 39	.006 - .010
40 and larger	.007 - .011

* NOTE: The clearances given in this table are for new machines. Machines which have been in service for some time may operate entirely satisfactorily with somewhat greater clearances.

After thermometer or relay bulbs have been installed, with due regard for insulation against shaft currents, the oil pans and vapor guards may be bolted in place. Clearances between these parts and the shaft must be adequate to prevent rubbing.

3-21 BEARING INSULATION

Most electrical machines have a tendency to produce shaft currents. These currents enter the shaft through the bearing at one end of the rotor and leave it through the bearing at the opposite end. Insulating the bearings **and all other paths** by which current can leave the shaft at one end of the rotor protects all bearings of a given machine. On vertical machines, the insulation is located above the rotor and none is required below the rotor.

A thrust bearing located above the rotor has insulation under the base ring. After the bearing is assembled and carrying the rotor weight, this insulation should be checked with a 500-volt insulation resistance meter. If the resistance of this insulation is less than 20,000 ohms, it should be corrected. Insulation in the upper guide bearing and any piping, railing, instruments, or other equipment leading to the upper end of the machine should be checked similarly.

> **NOTE:** *When the spring cage and base plate are factory assembled with insulation between them, this assembly should not be disturbed. If disassembly appears necessary, Large Motor and Generator Engineering, should be contacted for instructions.*

Bearing insulation may be either single or double. Single insulation consists of a single layer of insulation for each joint that is insulated. Double insulation consists of two layers of insulation with a metallic component between the layers. Double insulation may be tested by applying a voltage between the inner metallic component and the part of the machine on the opposite side of the insulated layer. Two methods of providing double insulation are shown in Figures 3-10 and 3-11.

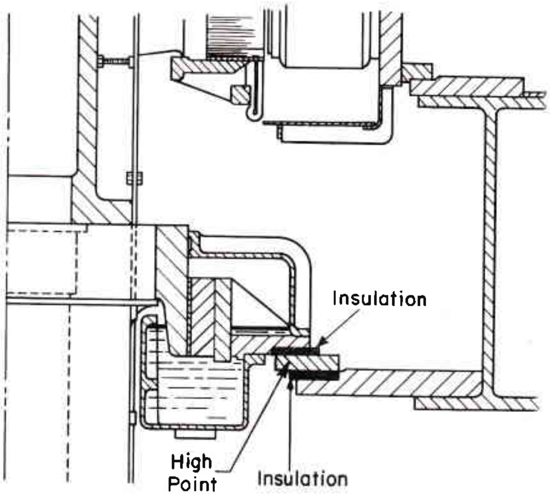

Fig. 3-10. A common method of providing double insulation.

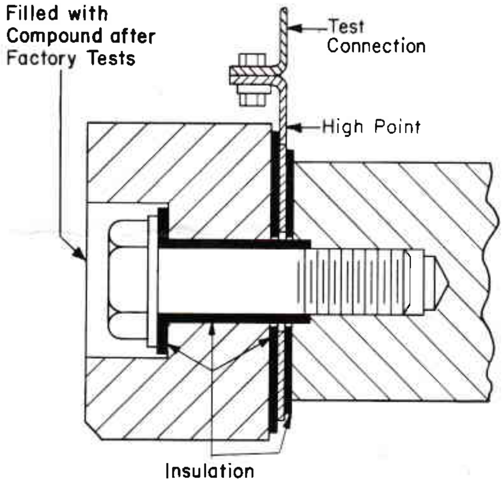

Fig. 3-11. A common method of providing double insulation. Note that insulated bolts are factory-tested and sealed. View also shows method of bringing out lead from "high point" for testing.

When single insulation is used, all return paths must be opened temporarily to test the insulation. All connections between the rotor and the frame at the lower end of the machine must be removed, or each insulated joint must be isolated and tested individually.

When double insulation is used, insulation of each joint may be checked with the machine completely assembled. However, it should be remembered that this checks only the particular joints that are tested and does not eliminate the possibility of an uninsulated shunt path.

There is no substitute for a complete visual inspection of all possible shunt paths for bearing current. This includes such temporary paths as tools, scrap material, or dirt.

3-22 OIL PIPING

The oiling system must be installed very carefully. Every length of pipe should be reamed at the ends and blown out with compressed air or steam before being connected. Rap the pipe with a rawhide or wooden mallet to dislodge any scale or chips while blowing out.

Use pipe compound or G-E No. 1201 Glyptal* varnish on all threaded joints. Flush the complete piping system with oil before placing it in service. Bearing cooling coils should be subjected to a suitable hydrostatic test before the housing is filled with oil.

It is extremely important to remove all dirt and other foreign matter from the bearing housings and piping before initial operation. The housings should be carefully cleaned and inspected, and the surfaces (except metal to metal fits) coated with G-E No. 1202 Glyptal varnish. To clean the pipes, oil should be circulated through them for several hours. The oil leaving the pipes should be by-passed from the housing and filtered to remove dirt. Finally, flush out the housing with filtered oil.

3-23 OIL RECOMMENDATIONS

The successful operation of electric motors and generators is vitally dependent upon proper lubrication of the bearings.

The oil used is the responsibility of the purchaser of the equipment and should be a high-grade, mineral oil that is recommended for electric motor or generator use by a reputable oil manufacturer.

The responsibility for recommending a suitable oil rests with the oil vendor. However, our experience indicates that medium-grade oils with the characteristics given in Table 3-9 are generally suitable

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* Registered Trademark of the General Electric Company.

TABLE 3-9

TYPICAL OIL CHARACTERISTICS

CHARACTERISTIC		REFERENCE METHODS PER ASTM SPEC. NO.
Viscosity, SSU at 100 F	270 to 325	D 88
Viscosity Index, Min	85	D 567
Flash Point, F Min	+400	D 92
Pour Point, F Max	+20	D 97
Neutralization Value, Max	0.15	D 974
Oxidation Inhibitor	Present	—
Corrosion Inhibitor	See Note 1	See Note 1
Oxidation Stability Test (Minimum hours to meet an Acid Number of 2.0 mg KOH per gram)	1000	D 943
Sludge % Max (On oil taken from Oxidation Stability Test)	0.10	D 1314 Sec. 12 (C only), Sec. 13, Sec. 14 (A only) will apply

Note 1—Oils with or without corrosion inhibitor are acceptable provided that they pass the ASTM D 665-54T rusting test and that the babbitt weight loss as determined in the modified ASTM D 943 oil test does not exceed 100 mg in 1000 hours. Testing instructions for the modified ASTM D 943 test and babbitt samples have been supplied to the major oil producers or are available to them upon request. Rev. 8-57

for lubrication of both G-E thrust and guide bearings in General Electric machines.

The oil should be a well-refined, straight-cut, petroleum product, free from water, sediment, resin, acids, soaps and detergents. Oils having these characteristics can be supplied by most major oil companies. Some oils marketed as electric motor and generator oil may have these characteristics. Automobile-engine oils should not be used.

Oils from different producers should not be mixed without the approval of the producers.

Excessive acidity of the oil causes very rapid babbitt disintegration. It is important, therefore, that the oil be checked periodically and discarded when the neutralization value exceeds 1.0 for dry oil. Wet oil (containing more than a few drops of water) should be replaced when the neutralization value exceeds 0.5.

The neutralization value is the weight in milligrams of potassium hydroxide required to neutralize a 1 gram sample of oil.

3-24 BRAKES AND JACKS

The function of brakes on a vertical-shaft generator is to stop the machine from coasting speed after the turbine gates have been closed and to hold it at rest against a small amount of gate leakage. **Never apply brakes during a runaway or even at normal speed.** Usually, the brakes are designed to bring the rotor from half-speed to rest in 5 minutes or less with an applied air pressure of 100 pounds per square inch.

When brakes are used as jacks to raise the rotor, oil is pumped into them at a presure of 1000 to 1500 pounds per square inch by means of a pump provided solely for that purpose.

The brakes and jacks are supplied from a loop header. Air for braking is admitted and released from one end of the loop. Oil for jacking is admitted and released from the opposite end. When oil is being admitted for jacking, the air in the pipes can be bled from the air end of the header. Similarly, when air is being admitted for braking, oil can be blown out of the oil end. On some machines, not all jacks are used as brakes.

Whenever the brakes are to be used as jacks, a blocking device is provided to hold the jacks in a raised position without depending on the maintenance of oil pressure.

If the rotor is not jacked at least once every six months, the chevron packing around the operating piston should be oiled. On jacks having cam-type blocking, the oil can be added through the hole left by removing the cap screw which passes through the upper cam. This screw must be replaced before the brakes or jacks are used. On the other style brakes, the oil can be added through the tapped hole in the side of the brake.

3-25 AIR GAP

The air gap should not vary at any point more than 12 percent above or below the value shown on the assembly drawing, and should be parallel from top to bottom. In measuring the air gap, particularly on machines with amortisseur windings, care should be used to measure from iron to iron at the tangential **center** of the pole face.

3-26 EXCITER ARMATURE INSTALLATION

Exciter armature for vertical machines is often designed with a flanged shaft with a rabbeted fit which bolts to the end of the generator shaft. Main and pilot exciter shafts may, in turn, have one or more bolted joints. The exciter-armature components are assembled in the factory, and adjusted for commutator concentricity.

Great care must be taken in assembling the exciter armature to the generator shaft. The least speck of dirt between flange faces, or uneven tightening of the coupling bolts will cause commutator run-out. Repeated trials and very careful work may be necessary to obtain a satisfactory assembly. Scraping of the coupling faces or shimming may be necessary in some cases.

There is several thousandths of an inch clearance in the guide bearings, and under some conditions the shaft may float in the bearings. It may, therefore, be impossible to get the commutator to run absolutely true. A small amount of runout may be expected and is not objectionable. Dial indicator checks for run-out should be made, rather than depending on visual observations.

3-27 BRUSHES AND BRUSH RIGGING

The type of brush holder commonly furnished is shown in Fig. 3-12. For more than two brushes per ring, spacers are used between individual brush holders and the bus bar to stagger the brushes across the width of the rings. This promotes uniform wear of the rings. Radial brush holders should be set 1/8 inch from the rings. Trailing brush holders are to be set 1/16 inch from the rings at the closest point. Brushes must move freely in the holders and at the same time make firm and even contact with the collector rings. Poor contact will cause sparking.

To fit the curvature of the brush to the curvature of the ring, use sandpaper with the sanded side out.

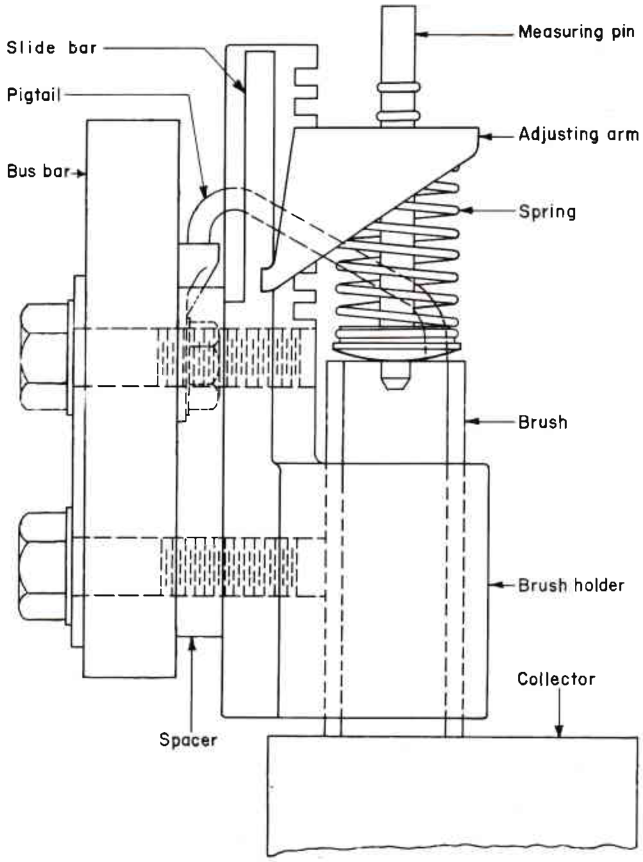

Fig. 3-12. A typical collector brushholder.

Draw it in the direction of rotation on the ring surface. Lift the brush when moving the paper back to its original position. Keep the ends of the sandpaper close to the collector ring to avoid rounding the edges of the brush. See that the pigtails do not interfere with the rigging.

Each brush is held against the ring by a helical spring bearing against the back of the brush and compressed by an arm. This arm can be set in various notches in the slide bar of the brush holder. The end of the spring next to the brush carries a metal button and a measuring pin with rolled projections. This pin extends through the arm when the spring is compressed. The brush pressure is indicated by the number of the rolled projections which are visible above the arm.

A brush pressure of 2 to 2½ pounds per square inch is recommended for carbon brushes, and 3 to 3½ pounds per square inch for metal-graphite brushes. This may be checked with a spring balance. These pressures may need to be increased slightly on collectors with high peripheral speeds to eliminate sparking.

When the brushes are first installed, adjust the position of the arm to obtain this force, and note the number of visible projections on the measuring pin. As the brushes wear, change the position of the arm to keep the measuring pin in the same relation to the arm. When the brushes have worn down to 1¼ inches, they should be replaced since the spring pressure can no longer be maintained.

3-28 COLLECTORS

Collector rings may be either of two types: The shrunk-on type consists of rings shrunk on a mica-covered, cast-iron sleeve. This sleeve is tapped or pressed on the shaft. The shell-mounted type consists of split or solid rings mounted by means of Mycalex insulators on a cast iron sleeve which fits the shaft.

Occasionally, shell-mounted rings may become misaligned due to rough handling. They may be realigned by slightly loosening the mounting studs and tapping the rings into position with a rawhide or wooden mallet. Care should be exercised when retightening the studs so as not to crack the insulators. The collector-ring eccentricity should be checked by means of a dial indicator mounted on a brush support.

A collector eccentricity of 1/32 inch does no harm on low-speed machines. The brushes can follow the rings readily at these low speeds and the movement may tend to keep them free in their holders.

Collector-ring surfaces can often be kept in better condition by periodically reversing the polarity of the brushes. When collector and exciter leads are brought out to a breaker, cables should be left long enough to permit such reversal. When collector and exciter leads are permanently connected within the machine, provision for reversal by interchanging connection strips is usually included. In making a reversal of polarity, the need for reversing instruments connected to the field should be considered.

3-29 BOLTING SUGGESTIONS

Before installing any large bolts or studs:

1. Inspect the bolts or studs and nuts to make sure that the threads are smooth and without burrs or bruises.
2. Be sure the threaded portion is long enough so that the nuts can be tightened before they jam on the end of the thread.
3. Make sure the nuts turn easily and are square with the body of the bolt.

4. With temporary bolts, use a polished washer between the nut and the surface being pulled up.

5. Lubricate the threads and the rubbing surface of the nuts with a mixture of powdered graphite and vaseline, or Gredag No. 81½.

In many cases, factory drawings give specific instructions for heating bolts to obtain the benefit of shrink tightening. When specific instructions have not been furnished, and shrink-tightening is desired, these recommendations should be followed:

1. Heat the bolts in a steam box, boiling water, or hot oil. In some cases, the thread fit is such that the nuts must be heated to avoid jamming on the hot, expanded bolt.

2. Bolts are frequently made of heat-treated alloy steel. Avoid heating these bolts above 300 C since their strength may be greatly reduced by overheating. Never use a direct flame to heat bolts.

3. The joints should be pulled together with bolts at room temperature. The bolts are then taken out, a few at a time, heated, and reinstalled.

4. Tighten the hot bolts with one man on the wrench.

5. Relative tightness can be approximately checked by sounding the bolts with a hammer.

In some instances, bolts are tightened while at room temperature to a specified value of stress. This is accomplished by actually measuring the stretch of the bolt with a micrometer device during tightening. Accuracy in measurement is very important.

Unless otherwise specified, medium-carbon steel bolts should be tightened approximately as shown in Table 3-10

TABLE 3-10

BOLT-TIGHTENING TORQUES FOR MEDIUM-CARBON STEEL BOLTS

Bolt Size	Torque (lb.-ft.)
3/8 - 16	7
1/2 - 13	17
5/8 - 11	35
3/4 - 10	60
7/8 - 9	100
1 - 8	150
1-1/4 - 7	300
1-1/2 - 6	500
1-3/4 - 5	800
2 - 4-1/2	1200

3-30 WELDING HAZARDS

One of the serious hazards to machine bearings is electric welding on the machine or any equipment connected to it (especially the turbine or pump runner). A bearing can be seriously damaged by passing welding current through it.

For this reason, it is desirable to lift the rotor off the thrust bearing whenever any electric welding is being performed on the turbine (pump) or generator (motor). Also, the ground cable from the welder should be connected directly to the part being welded and to no other part of the machine.

INITIAL OPERATION

4-1 GENERAL

When a machine is being started for the first time or after a long shutdown or extensive repairs, there are several items to be considered in addition to the normal operating procedure. The most common of these additional items are listed in this section.

The specific instructions for the control equipment and switchgear should be read before operating a machine.

4-2 BEFORE INITIAL STARTING

Following are some of the things which should be done or checked before initially starting a machine:

1. IMPORTANT: During the last few days before a machine is first started and after all welding has been finished, the oil should be drained and the thrust bearing parts removed. The bearing surfaces should be carefully inspected for scratches, rust, imbedded metallic or abrasive particles, or welding marks. When the rotor is being shifted during alignment, small scratches are sometimes formed on the bearing surfaces, and when welding is performed on the machine (especially the rotor), stray currents sometimes damage the bearing surfaces. These scratches or welding marks could cause a bearing failure if left uncorrected.

After the bearing has been inspected it should be coated with Gredag No. 81½ and reinstalled. The rotor should then be lowered onto the thrust bearing and the bearing and the housing filled, flushed, and refilled with clean, carefully-filtered oil.

After this inspection, the weight of the rotor should not be lifted off the thrust bearing until after the machine has been run.

If the conditions of installation are especially dirty, this inspection should be one of the last operations before the machine is started.

2. Flush out the other bearings and housings with clean lubricating oil in order to remove any grit or dirt that has accumulated during shipment or installation.

3. Using a good grade of lubricating oil selected in accordance with "Oil Recommendations," Sec. 3-23, fill the oil reservoirs to the oil-level line marked on the machine and shown on the drawings. When filling the bearing housings, filter the oil directly at the machine even if it is being taken from new barrels.

4. Examine the interior of the stator frame, the exciters, the collector rings, the air gap, the top of the rotor, and the spaces between the poles for loose objects (bolts, nuts, tools, etc.). Use a magnet to remove all small iron or steel particles. Make sure that all nuts and bolts that could drop into the rotor are locked.

5. Make sure that all moving parts have sufficient clearance from the nearest stationary parts. Pay particular attention to the clearance between the pole faces and the stator.

6. Check the electrical clearance around all parts which are to be energized.

7. Check tightness of all foundation bolts and holding-down bolts.

8. See that all protective devices (relays, overspeed devices, etc.) are operating properly.

9. Remove all dirt and grit from commutators and collectors.

10. Turn on the bearing cooling water just before starting the machine.

In addition to the above, the following additional steps should be taken before initially starting a motor:

11. Check to see that the brushes are on the collector rings, and that the field winding will be short circuited through a resistor during starting.

12. Be sure that power of the correct voltage, frequency, and phase sequence is being applied.

13. Be sure the windings are clean and dry (see Sec. 3-8) before full voltage is applied.

4-3 INITIAL STARTING

When starting a generator for the first time, the following general starting procedure is suggested:

1. Start the machine and quickly bring it up to 1/3 to 1/2 rated speed so that the bearing oil film will be built up quickly.

2. Hold this speed constant and note the bearing temperatures at one-minute intervals until they become constant. Any continued or rapid rise of bearing temperature indicates a damaged rubbing surface.

3. If the bearing temperatures have become constant and the machine is operating smoothly, the

speed may be gradually increased to normal. If vibration is excessive, the rotors should be balanced.

4. Before paralleling a generator with another generator, check the synchroscope and phase sequence as described in Sec. 4-4.

Unless otherwise specified, most vertical motors and generators have guide bearings and/or fans which are designed for only one direction of rotation. The correct direction of rotation is shown by a rotation nameplate attached near the machine nameplate (or by the outline drawing on large machines). Rotation in the wrong direction may result in improper lubrication of the guide bearings and/or improper ventilation.

4-4 CONNECTION TO THE POWER SYSTEM

The phase sequence of generators should be checked before connection to the power system.

On motors, shaft rotation should be checked before coupling to driven equipment, especially if the equipment will be damaged by incorrect rotation.

Synchronous motors and generators are wound so that the voltage has a phase sequence of T_1-T_2-T_3 for clockwise rotation of the rotor when the rotation is viewed from the armature-coil-connection end. It is recommended that both the synchroscope connections and the phase-sequence be tested before the machine is connected because considerable damage can result if either is incorrect.

A method for testing phase sequence and checking the synchroscope connections is as follows: With the generator leads disconnected at the generator terminals and the bus energized, close the main circuit breaker. The synchroscope will indicate the position which the pointer will occupy when the generator is in synchronism. If the pointer is on the synchronizing mark, the potential transformers and synchroscope are properly connected. If the pointer is at an angle, the connections are incorrect and should be changed. A phase-sequence indicator should then be connected to the potential transformer on the generator side of the main circuit breaker and the phase-sequence indication noted. The circuit breaker should then be opened and the generator leads temporarily connected. With the generator running and excited, note the phase-sequence indication. If the phase-sequence indication is the same in both cases, the generator leads can be permanently connected with assurance that the phase-sequence and synchronizing connections are correct. If the phase-sequence is incorrect, interchange any two of the three-phase terminal leads. For a two-phase generator interchange the two leads of either phase.

4-5 BALANCING

Before a machine is placed in regular service, any abnormal vibration should be corrected.

If at any time it becomes necessary to remove balance weights they should be replaced in exactly the same position.

Before disassembling a pole on a high-speed machine, the axial position of that pole should be accurately marked so that it can be replaced in the same position.

Should it become necessary to replace a field coil or a complete pole, the balance must be checked. When balance weights are added to a rotor, they should be fastened to the web of the spider or spider arms, not to the rim.

Common causes of undue vibration (other than unbalance) are: misalignment, an improper or a settled foundation, uneven air gap, parts rubbing the rotating element, bent shaft, a short-circuited field coil, or unbalanced stator currents. These should be investigated before balance weights are added or shifted.

4-6 THRUST-BEARING-SEGMENT VERTICAL MOVEMENT

After the machine is in final balance, the vertical movement of the thrust bearing segments should be checked with the machine rotating. This will give an indication of the alignment of the face of the thrust collar.

This check should be made with the machine running at a speed of the order of 50 rpm and decelerating. If the vertical movement is greater than 0.002 inch, the misalignment should be corrected.

A convenient way to measure this movement is to screw a pin into the radial hole in the outer edge of a thrust-bearing segment. Then, thread a vertical rod into this pin so that it extends through the cover of the bearing housing. The vertical movement of this rod (and the bearing segment) can be measured with a dial indicator.

NORMAL OPERATION

5-1 GENERAL

The operating procedures will vary considerably depending on the application of the machine and the type of control equipment used. Only the general procedures are outlined here, and some of the components mentioned may not be present in a particular application.

> **NOTE:** *The following general precautions should be taken when operating any machine:*
>
> *DO NOT attempt to open a field circuit suddenly because the inductive-discharge voltage will be very high and may puncture the field insulation or injure the operator. A field switch or breaker should be specially designed for this service and should have a discharge resistor which is connected across the field when the switch is opened. In an emergency, a field circuit can be broken by opening the switch SLOWLY and allowing the field to discharge across a very short arc formed at the switch terminals (this should be done with a switch hook—NEVER with the bare hands).*
>
> *DO NOT operate a machine with less field current than the value required for unity power-factor unless a study has shown that the machine will be stable at the lower value of excitation.*
>
> *DO NOT operate a machine with more than rated field current, armature current, or armature voltage. If any one of these values is exceeded some portion of the machine is being overloaded.*

5-2 OIL PRESSURE STARTING

High-pressure oil is sometimes used to establish the oil film in a bearing before the machine is started. This reduces or eliminates the metal-to-metal contact and wear of the bearing surfaces during the fraction of a revolution required to establish an oil film.

If the machine bearings are equipped with high-pressure oil pumps, the pumps should be started before the machine is started, and shut down when the machine comes up to speed. The high-pressure oil pump is not needed when the machine is being shut down.

5-3 NORMAL STARTING

Generator Starting

When starting a generator, the following steps should be included:

1. Start the oil-pressure-starting pump and allow the pressure to build up. (Note: On machines which do not have oil-pressure-starting equipment, some operators lift the rotor by means of the jacks in an attempt to build up an oil film on the thrust bearing just before starting. This is not considered necessary with a G-E thrust bearing.)
2. See that the circuit breakers between the generator and all loads are open.
3. Set the field-current control for minimum field current.
4. Turn on the water to the oil and air coolers.
5. Start the machine and quickly bring it up to speed.
6. Shut down the oil-pressure-starting pump when the generator is up to speed.

Motor Starting

Most applications of large synchronous motors employ automatic or semi-automatic control which takes care of the proper sequence of switching for both starting and stopping. The instructions accompanying the control equipment should be carefully reviewed before operating the equipment.

When starting a motor, the following steps should be included:

1. Start oil-pressure-starting pump and allow pressure to build up.
2. Turn on the water to the oil and air coolers.
3. Reduce the shaft load as much as possible.
4. Apply power to motor and bring it up to speed quickly.
5. Apply field excitation and synchronize.
6. Shut down the oil-pressure starting system.

With automatic starting equipment, steps 4 and 5 will be performed automatically after the "start" button is pressed.

With semi-automatic starting equipment, step 4 will be performed by pressing the "start" button and it will be necessary to press the "run" button to perform step 5.

In both types of starters, the field is automatically applied at the proper speed and at a consistently favorable angle.

The selection of autotransformer, resistor, or reactor tap will depend upon the machine size, the load, and the allowable starting current. Do not use a tap which permits unnecessarily slow acceleration at any part of the starting cycle.

> **CAUTION:** *DO NOT touch the collector rings, field switch, rheostat handwheel, or brushes when the motor is being started. An induced voltage of several thousand volts may exist across the rings at the moment of starting. This voltage is zero at synchronous speed.*

5-4 SYNCHRONIZING AND LOADING A GENERATOR

To synchronize a generator with a bus:

1. With the machine at rated speed, increase the field current until the terminal voltage is approximately equal to the bus voltage.
2. Put the voltage regulator in service and allow it to control the machine voltage.
3. Adjust the terminal voltage until it is equal to the bus voltage.
4. Vary the speed of the incoming generator until the generator voltage and the bus voltage are in phase.
5. With the generator voltage and the bus voltage equal and in phase, close the circuit breaker which connects the generator to the bus.

To increase the power (kw) output of the generator increase power output of the turbine.

To increase the reactive (kvar) output of the generator, increase the field current. (If the machine voltage is being controlled by a voltage-regulator, this is done by increasing the voltage setting of the regulator.)

> **NOTE:** *A change in generator loading may necessitate a change in water flow to the air coolers.*

5-5 FREQUENT STARTING

When a generator is being used to carry intermittent loads, it is undesirable to stop and restart the machine for short (less than 2 hours) periods of no load. It is better to reduce the speed and allow the machine to coast at not less than 30 rpm. This speed can often be obtained from gate leakage alone without any additional use of water.

> **NOTE:** *The machine must always be brought up quickly to above 1/3 speed when started from rest.*

5-6 FIELD EXCITATION OF A MOTOR

The armature current and the power factor of a synchronous motor depend upon the shaft load and the field current. At a constant load, the variation in armature current with a change in field current is shown by the solid lines of Fig. 5-1 (These are called V-curves because of their shapes). For a given load, unity-power-factor operation is obtained by adjusting the field current for minimum armature current with that load. The dashed curve of Fig. 5-1 shows how the field current varies with armature current for unity-power-factor operation.

If the field current is less than that which is required for unity-power-factor operation, the motor is said to be "underexcited" and it is operating at a lagging power-factor and drawing magnetizing current from the line. If the field curent is greater than that which is required for unity-power-factor operation the motor is said to be "overexcited" and it is operating at a leading power-factor and is sup-

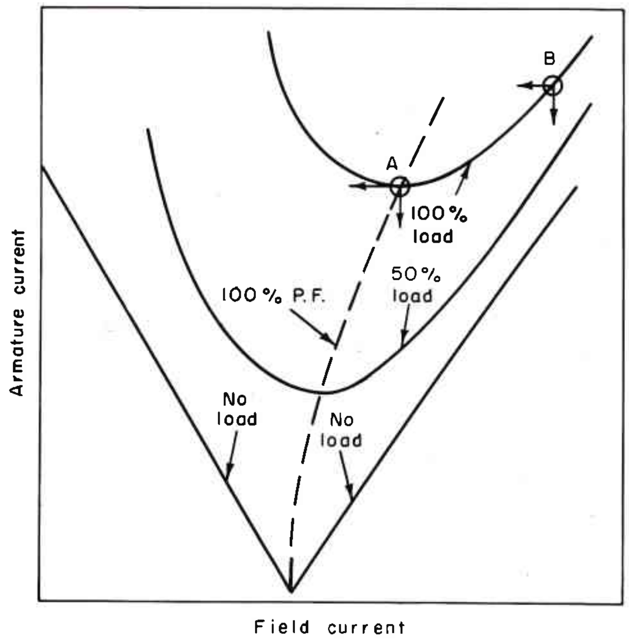

Fig. 5-1. Typical V-curves for a synchronous machine.

plying magnetizing current to the line. The power-factor rating given on the nameplate of a synchronous motor, if less than unity, always means leading power-factor (overexcited).

Unity-power-factor motors are designed to operate at rated load as shown by Point A on Fig. 5-1. The field current and armature current values given on the nameplate are for this rated-load condition.

Leading-power-factor motors are larger than unity-power-factor motors of the same horsepower rating. Leading-power-factor motors have additional stator and field winding capacity and are designed to operate at rated load as shown at Point B on Fig. 5-1. The field and armature currents given on the nameplate are for this rated-load condition.

Synchronous motors may be operated with rated field excitation at partial loads. In such cases they are overexcited and supply leading reactive to the power system. The approximate magnitude of this reactive can be determined from Fig. 5-2.

If it is desired to determine the actual power factor at which a synchronous motor is operating; read the line current (I_A) at the desired condition of operation and then change the field excitation until the line current is at a minimum (I_M) which corresponds to unity-power-factor operation. If the horsepower load has remained constant, the power factor at the first condition is given by the ratio of the two line currents:

$$\text{power factor} = \frac{I_M}{I_A}$$

5-7 STOPPING A GENERATOR

To stop a generator:

1. Reduce the turbine output until the kilowatt output of the generator is almost zero (this may require, simultaneously, a reduction of the field current to prevent overvoltage).

2. Reduce the field current until the armature current is almost zero.

3. Trip the armature circuit-breaker.

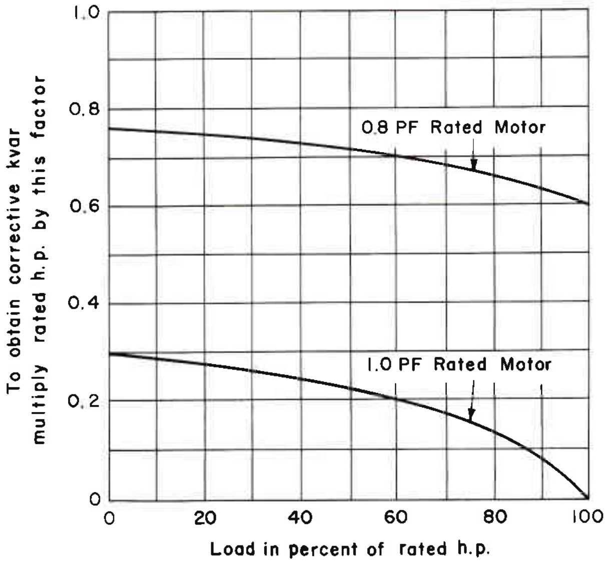

Fig. 5-2. The approximate leading kvar supplied by a synchronous motor with rated field current.

4. Reduce the turbine output to a minimum.

5. Allow the generator to slow to coasting speed or 30 rpm, whichever is greater.

6. Apply brakes until the generator comes to rest and for at least 10-15 minutes thereafter.

NOTE: *Generator must be below 1/2 speed before brakes are applied.*

7. Reduce the field excitation to zero when the generator comes to rest.

8. Shut off the cooling water.

5-8 STOPPING A MOTOR

To stop a motor:

1. Reduce the load as much as possible.

2. Open the armature circuit-breaker.

3. Reduce the field current to zero when the motor comes to rest.

4. Shut off the cooling water.

MAINTENANCE

6-1 MAINTENANCE AND INSPECTION

Maximum availability of equipment and minimum maintenance cost are results of a carefully planned and executed program of inspection and maintenance.

When it is necessary to repair, recondition, or rebuild your electrical apparatus, we recommend that your nearest General Electric service shop be consulted. Factory trained personnel using factory methods and shop facilities and genuine General Electric renewal parts are available to you day and night. In addition, the services of our factory, engineering organizations, and sales offices are available to assist you with your engineering problems. Contact the nearest service shop or sales office listed on the back page of this book.

In addition to daily observation of the overall condition and operation of the machine, it is recommended that a regular inspection routine should be set up to periodically check the following items:

Cleanliness

The interior and exterior of the machine should be kept free from dirt, metallic particles, oil, and water. The ventilating air should be kept as clean as possible. When dirt is deposited on the windings and in the ducts in the core, it increases the temperature rise of the machine and reduces the safe operating capacity. Before cleaning a machine, see the discussion of cleaning in Sec. 6-3.

Lubrication

The oil reservoirs should be kept filled to the recommended oil level with a good grade of lubricating oil, (See "Oil Recommendations," Sec. 3-23). The oil should be checked every six months or oftener, depending on such conditions as cleanliness and severity or continuity of service. It should be reconditioned or replaced as necessary. Oil should be filtered directly at the bearing housing as it is added.

Cooling Coils

The inside of a cooling coil accumulates scale or sludge from hard or dirty water and should be cleaned regularly. Scale can be removed by a solution of equal parts of water and hydrochloric acid (muriatic acid). Ram-rod type brushes or scraper plugs may be used to clean the straight tubes found in certain types of coolers. If sludge deposits on the coils, the outside also should be cleaned. Machines which are shut down should have the water blown out of the cooling coils if there is any danger of freezing.

Bearing Insulation

Bearing insulation should be checked periodically with a 500 volt insulation tester.

Vibration

Any evidence of increase in machine unbalance or vibration should be investigated immediately.

Commutators, Collectors, and Brushes

The collector ring surfaces and the commutator surface should be inspected frequently. Brushes should move freely in their brush holders. Worn brushes should be replaced with brushes of the same grade.

The collector rings, commutators, and brush rigging should be cleaned by wiping carefully with dry, lint-free cloths. Care should be taken to prevent cleaning fluids or their fumes from contacting collector or commutator surfaces. The surface films are sensitive to these fluids. Fine-grained stones may be used to remove pitted and rough spots from the collectors.

Stationary Parts

An occasional inspection of windings, frames, and other parts should be made. Holding-down bolts, foundation bolts, and core-clamping bolts should be inspected occasionally to see that they are tight. Particular attention should be given to the bolts used to clamp any insulation.

Foundation caps should also be checked periodically for evidence of lack of support due to foundation settling. On a large machine, the record of the wye-level readings made during installation can be used to check for non-uniform settling of the foundation.

Rotating Parts

The rotor-pole bolts or keys of a-c machines should be tightened securely when the machine is being erected, checked after the equipment has run for a short time, and checked at regular intervals thereafter.

In case the inspection of the rotor shows that there are loose pole-piece keys or bolts, a check should be made for evidence of additional damage. Loose keys or bolts may result in worn keys, damaged amortisseur windings, or broken, end-plate dovetails. There will usually be sufficient stock for tightening the keys. However, in some cases it may be necessary to drive out the keys and insert shims, or to replace the keys with larger ones.

Ordinarily two or three drivings (or tightenings) will assure that the keys (or bolts) stay tight, but they should be checked regularly anyway.

Windings

Readings of insulation resistance should be taken regularly, particularly during damp weather or after a long shutdown.

Low insulation resistance or sudden changes in insulation resistance should be investigated carefully. Where the insulation resistance is low as a result of dirt or excessive moisture, it can usually be brought up to a proper value by cleaning to remove the dirt, and by drying to remove the moisture.

Machines Out of Service

Machines that are to be out of service for any extended period require special care. They should be kept slightly above room temperature by means of space heaters. This is to avoid moisture condensation with consequent lowering of the insulation resistance of the windings and rusting of metal parts.

The brushes should be lifted from the collectors. If moisture conditions are bad, the rings should be coated with vaseline.

The exciter brushes should be lifted, but the commutator should not be oiled.

All water lines, cooling coils, etc., should be drained to reduce corrosion and prevent freezing.

6-2 OPERATIONAL DIFFICULTIES

Vibration

If the vibration occurs when the field is not excited, check for evidence of misalignment, settling of foundation, or parts rubbing the rotating element. After these factors have been corrected, further refinement of balance may be desirable.

If the vibration occurs only when the field is excited, make sure the air-gap is uniform and check for grounds or short-circuited turns in the field windings. The air gap should be corrected if necessary.

Heating

Do not depend on the hand to determine temperatures; use a thermometer. If there is any doubt about the safe operating temperature, read the temperature of the part in question and confer with the nearest office of the General Electric Company. Give full details, including all nameplate information.

Low Voltage

The generator voltage may be low because:

The speed of the generator is below normal.

The switchboard instruments are incorrect, and the voltage may be higher than that indicated, or the current may be greater than is shown by the readings.

The power-factor of the load may be abnormally low.

The exciter voltage and generator field current is low.

The voltage of the exciter may be low because:

The speed is below normal.

The series field is reversed.

Part of its shunt field is reversed or short-circuited.

The brushes are set incorrectly.

Part of the field rheostat or other unnecessary resistance is in the field circuit.

6-3 CLEANING WINDINGS

The method of cleaning must necessarily vary considerably with the amount and kind of dirt to be removed.

Dry dust, lint, and other debris can often be removed with a vacuum cleaner or dry, compressed air. (Compressed air should be used with care to prevent damage to the insulation from high-velocity flying particles).

When fresh oil or grease is to be removed from windings, Freon No. 113* is recommended as a cleaning solvent. It will readily remove oil or grease that has not hardened and will not attack the insulating varnish.

Oil or grease that has dried and hardened is more difficult to remove. Chlorothene** (inhibited 1,1,1, trichloroethane) is recommended as a solvent in this case. It is a more active solvent and may attack the insulating varnish. Therefore, the windings and core may need to be sprayed with G-E No. 7144 air-drying varnish after cleaning with Chlorothene (allow the varnish to dry thoroughly before operating the machine).

---

* A product of the DuPont Company.

** A product of the Dow Chemical Company.

Either cleaning solvent should be applied in such a manner as to obtain rapid cleaning without subjecting the windings to the cleaner for an undue length of time.

After cleaning, the winding must be thoroughly dry before spraying with varnish or applying voltage. Resistance measurements are not a reliable measure of insulation dryness in this case.

> **CAUTION:** *Most cleaning solvents in common use are highly toxic, highly inflammable or both.*
>
> *Before using any cleaning solvent, read the discussion in Section 6-4.*
>
> *Although both Freon No. 113 and Chlorothene are considered non-inflammable and have a relatively low order of toxicity, prolonged exposure to either liquid or vapor should be avoided. They should be used only in a well ventilated area away from open flame.*

6-4 SAFETY PRECAUTIONS

Some hazards that might be overlooked are mentioned in the following discussion.

Working on Rotor

When there is water in the scroll case, there is always some danger of the machine being rotated by gate leakage. Therefore, the brakes should be applied and/or the scroll case drained whenever anyone is working on or around the rotor.

CO_2 Discharge

When a CO_2 fire-protection system is used, the tripping mechanism should be disabled before anyone is allowed to enter the protected area.

Since CO_2 is heavier than air, it collects in low, unventilated spaces. After a CO_2 discharge, these spaces should be checked to determine if there is adequate oxygen before anyone enters them. (Before checking for CO_2 with an open flame, be sure that there is no inflammable vapor present).

Cleaning Solvents, Paints, and Varnishes

Most cleaning solvents, paints, and varnishes are highly inflammable or toxic or both. Unless it is definitely known that a cleaning solvent, paint, or varnish is non-inflammable and non-toxic, it should be used only in a well ventilated place away from open flames, sparks, and energized electric equipment.

When using cleaning solvents, paints, or varnishes in appreciable quantities, one person should not be allowed to work alone, but should be accompanied with at least one other person who could give aid in case he were overcome by the fumes.

RENEWAL PARTS

7-1 ORDERING INSTRUCTIONS

When ordering renewal parts, state the quantity desired, the complete nameplate rating, and the serial number of the machine.

If there is any uncertainty as to exactly what is required, a sketch of the part wanted, giving all the necessary dimensions, should accompany the order.

Parts for any accessory that is not made by the General Electric Company may be ordered direct from the manufacturer. When ordering, give the data on the manufacturer's nameplate.

7-2 RECOMMENDED RENEWAL PARTS LIST

The renewal parts recommended are those most subject to wear, damage, or breakdown. The supply of spare parts that should be maintained depends upon the loss that may be sustained during the time required to procure parts after an unexpected failure.

The quantities recommended in Table 7-1 are given only as a guide, but are believed to offer reasonable security against normal operating hazards. Where continuous operation is of paramount importance, consideration should be given to increasing the quantities shown.

7-3 STORAGE OF RENEWAL PARTS

Store spare parts in a clean, dry, ventilated place, protected from rodents and termites. Slush all finished iron or steel surfaces with heavy oil or a slushing compound to protect them from corrosion. The parts should be inspected occasionally to insure their continuous usability.

A thrust-bearing runner should be cleaned on arrival (See Sec. 3-19) and carefully inspected. It should then be recoated with G.E. No. 280 slushing compound, repacked, and stored in a dry place which has a relatively uniform temperature. Unless there is evidence of damage, the stationary segments need not be unpacked, but should be stored in a dry place.

TABLE 7-1

Units in Use	1 - 2	3 - 5
Type of Machine and Name of Part	**Recommended For Stock**	**Recommended For Stock**
A-C Motors, Generators		
Stator Coils	1/3 Set	1 Set
*Field Coil	2	2
†Thrust Bearing Runner Plate and Stationary Segments	1 Set	1 Set
Upper Guide Bearing	1	1
Lower Guide Bearing	1	1
Brake Shoes	1 Set	2 Sets
Brush Holders	1/2 Set	1 Set
Brushes	1 Set	2 Sets
Exciters		
**Armature (complete)	1	1
**Field Pole (complete with windings)	1	1
**Commutating Pole (complete with windings)	1/4 Set	1 Set
Brush Holders for One Stud	1 Set	2 Sets
Brushes	1 Set	2 Sets

* When field coil is wound on the pole, a complete pole with winding may be necessary.

** Need not be carried as spares if separate source of excitation is available.

† It is not advisable to replace wiped bearing segments without also replacing the running plate.

WHEN YOU NEED SERVICE

IF YOU NEED TO REPAIR, recondition, or rebuild any electric apparatus, a G-E service shop near you is available day and night, seven days a week, for work in the shops or on your premises. Latest factory methods and genuine G-E renewal parts are used to maintain the original performance of your G-E equipment. For full information about these services, contact the nearest service shop or sales office listed below:

APPARATUS SERVICE SHOPS

ALBANY, NY	Central Ave.
Allentown, Pa.	672–676 E. Highland St.
Appleton, Wisc.	Midway Industrial Area, County Trunk, "P"
Atlanta—Chamblee, Ga.	4639 Peachtree Indus. Blvd.
Baltimore 30, Md.	920 E. Fort Ave.
Boston—Medford 55, Mass.	Mystic Valley Pkwy.
Buffalo 11, N. Y.	318 Urban St.
Charleston 28, W. Va.	306 MacCorkle Ave., S.E.
Charlotte, N. C.	2328 Thrift Road
Chicago 32, Ill.	4360 W. 47th St.
Cincinnati 2, Ohio	444 W. Third St.
Cleveland 4, Ohio	4966 Woodland Ave.
Columbus 23, Ohio	2128 Eakin Rd.
Corpus Christi, Texas	115 Busse St.
Dallas 19, Texas	3202 Manor Way
Davenport—Bettendorf, Ia.	1039 State St.
Decatur, Ill.	2225 E. Logan St.
Denver 5, Colo.	3353 Larimer St.
Detroit 2, Mich.	5950 Third Ave.
Houston 20, Texas	5534 Harvey Wilson Drive
Indianapolis 22, Ind.	1740 W. Vermont St.
Johnstown, Pa.	841 Oak St.
Kansas City, Mo.	3525 Gardner Ave.
Los Angeles 1, Calif.	6900 Stanford Ave.
Louisville, Ky.	2014 New Main St.
Midland, Tex.	3404 Bankhead Hwy.
Milwaukee 3, Wisc.	940 W. St. Paul Ave.
Minneapolis 12, Minn.	2025 49th Ave., N.
New Orleans, La.	2815 N. Robertson St.
New York—N. Bergen, N. J.	6001 Tonnelle Ave.
Oakland, Calif.	1525 Peralta St.
Philadelphia 24, Pa.	1040 E. Erie Ave.
Pittsburgh 6, Pa.	6519 Penn Ave.
Portland 10, Oregon	2727 N.W. 29th Ave.
Richmond 24, Va.	1403 Ingram Ave.
Roanoke, Va.	115 Albermarle St.
Sacramento, Calif.	99 N. 17th St.
St. Louis 10, Mo.	1115 East Road
Salt Lake City 4, Utah	301 S. Seventh West St.
San Francisco 3, Calif.	1098 Harrison St.
Seattle 4, Wash.	3422 First Ave., S.
Southington, Conn.	53 Railroad Ave.
Spokane 3, Wash.	S. 155 Sherman St.
Tampa 1, Fla. Miami	P.O. Box 1245, Naval Indus. Res. Shipyard
Toledo 4, Ohio	1 So. St. Clair St.
Wheeling, W. Va.	2050 National Rd.
York, Pa.	54 N. Harrison St.
Youngstown 5, Ohio	272 E. Indianola Ave.

APPARATUS SALES OFFICES

Abilene, Texas	442 Cedar St.
Akron 8, Ohio	335 S. Main St.
Albany 7, N. Y.	90 State St.
Albuquerque, N. Mex.	323 Third St., S.W.
Alexandria, La.	720 Murray St.
Allentown, Pa.	1132 Hamilton St.
Amarillo, Texas	Amarillo Bldg.
Appleton, Wisc.	531 W. College Ave.
Atlanta 3, Ga.	1860 Peachtree Rd., N.W.
Augusta, Ga.	Masonic Bldg.
Augusta, Me.	152 State St.
Baltimore 1, Md.	111 Park Ave.
Bangor, Maine	77 Central St.
Baton Rouge 6, La.	3170 Florida Blvd.
Battle Creek, Mich.	25 W. Michigan Ave.
Beaumont, Texas	1385 Calder Ave.
Billings, Mont.	Rm. 816, 303 No. Broadway
Binghamton, N. Y.	19 Chenango St.
Birmingham 3, Ala.	1804 Seventh Ave., N.
Bismarck, N. Dak.	418 Rosser Ave.
Bluefield, W. Va.	704 Bland St. Appalachian Bldg.
Boise, Idaho	1524 Idaho St.
Boston 1, Mass.	140 Federal St.
Buffalo 3, N. Y.	535 Washington St.
Butte, Mont.	P.O. Box 836, 103 N. Wyoming St.
Canton 2, Ohio	700 Tuscarawas St., W.
Cedar Rapids, Iowa	210 Second St., S.E.
Charleston 28, W.Va.	306 MacCorkle Ave., S.E.
Charlotte 1, N. C.	112 S. Tryon St.
Chattanooga 2, Tenn.	832 Georgia Ave.
Chicago 80, Ill.	P.O. Box 5970A, 840 S. Canal St.
Cincinnati 2, Ohio	215 W. Third St.
Cleveland 4, Ohio	4966 Woodland Ave.
Columbia 1, S.C.	P.O. Box 1434, 1420 Lady St.
Columbus 15, Ohio	40 S. Third St.
Corpus Christi, Texas	205 N. Chaparral
Dallas 2, Texas	1801 N. Lamar St.
Davenport—Bettendorf, Ia.	1039 State St.
Dayton 2, Ohio	11 W. Monument Bldg.
Dayton 9, Ohio	Avia. & Def., 2600 Far Hills Ave.
Denver 2, Colo.	650 Seventeenth St.
Des Moines 9, Iowa	505 W. Fifth Ave.
Detroit 2, Mich.	700 Antoinette St.
Duluth 2, Minn.	14 W. Superior St.
Elmira, N. Y.	Main and Woodlawn Aves.
El Paso, Texas	215 No. Stanton
Erie, Pa.	1001 State St.
Eugene, Ore.	Cascade Bldg., 1170 Pearl St.
Evansville 19, Ind.	123 N.W. Fourth St.
Fairmont, W. Va.	310 Jacobs Bldg., P.O. Box 1626
Fergus Falls, Minn.	108 N. Court Ave. P.O. Box 197
Flint 3, Mich.	653 S. Saginaw St.
Fort Wayne 6, Ind.	3606 So. Calhoun St.
Fort Worth 2, Tex.	408 W. Seventh St.
Fort Worth, Tex.	Avia. & Def., 6200 Camp Bowie Blvd.
Fresno 1, Calif.	407 Patterson Bldg. Tulare and Fulton St
Grand Rapids 2, Mich.	425 Cherry St., SE
Greensboro, N. C.	301 S. Elm St.
Greenville, S. C.	108 W. Washington St.
Gulfport, Miss.	207 Jo-Fran Bldg.
Hagerstown, Md.	Professional Arts Bldg.
Hartford 5, Conn.	764 Asylum Ave.
Houston 1, Texas	1312 Live Oak St.
Indianapolis 4, Ind.	110 N. Illinois St.
Jackson, Mich.	120 W. Michigan Ave.
Jackson 1, Miss.	203 W. Capitol St.
Jacksonville 2, Fla.	700 E. Union St.
Jamestown, N. Y.	P.O. Box 548, 2 Second St.
Johnstown, Pa.	841 Oak St.
Joplin, Mo.	P.O. Box 948, 220½ W. Fourth St.
Kalamazoo 3, Mich.	112 Parkway Ave.
Kansas City 6, Mo.	106 W. Fourteenth St.
Knoxville 16, Tenn.	1301 Hannah Ave.
Lake Charles, La.	422 Seventh St.
Lansing 8, Mich.	306 Michigan National Tower
Lexington, Ky.	First National Bank Bldg.
Lincoln 8, Nebr.	Sharpe Bldg., 206 S. 13th St.
Little Rock, Ark.	103 W. Capitol Ave.
Los Angeles 54, Calif.	212 N. Vignes St.
Louisville 2, Ky.	455 S. Fourth St.
Lubbock, Texas	3302 Avenue "A"
Macon, Ga.	682 Cherry St.
Madison 3, Wisc.	16 N. Carroll St.
Manchester, N. H.	875 Elm St.
Medford, Ore.	P.O. Box 1349, 107 E. Main St.
Memphis 3, Tenn.	8 N. Third St.
Miami 32, Fla.	25 S.E. Second Ave.
Midwest City, Okla.	Avia. & Def., 207 Post Off. Bldg.
Milwaukee 3, Wisc.	940 W. St. Paul Ave.
Minneapolis 3, Minn.	12 S. Sixth St.
Mobile 13, Ala.	54 St. Joseph St.
Nashville 3, Tenn.	234 Third Ave., N.
Newark 2, N. J.	744 Broad St.
New Haven 6, Conn.	129 Church St.
New Orleans 12, La.	837 Gravier St.
New York 22, N. Y.	570 Lexington Ave.
New York	Avia. & Def., Fed. Bldg., N. Y. International Airport, Jamaica 30, N. Y.
Niagara Falls, N. Y.	253 Second St.
Norfolk 10, Va.	229 W. Bute St.
Oakland 12, Calif.	409 Thirteenth St.
Oklahoma City 2, Okla.	119 N. Robinson St.
Omaha 2, Nebr.	409 S. Seventeenth St.
Pasco, Wash.	824 W. Lewis St.
Peoria 2, Ill.	309 Jefferson Bldg.
Philadelphia 2, Pa.	1405 Locust St.
Phoenix, Ariz.	P.O. Box 4037, 303 Luhrs Tower
Pittsburgh 22, Pa.	The Oliver Bldg., Mellon Sq.
Portland 7, Ore.	920 S.W. Sixth Ave.
Providence 3, R. I.	Industrial Trust Bldg.
Raleigh, N. C.	Room 401, 16 W. Martin St.
Reading, Pa.	31 N. Sixth St.
Richmond 17, Va.	700 E. Franklin St.
Riverside, Calif.	3570 Ninth St.
Roanoke 16, Va.	920 S. Jefferson St.
Rochester 4, N. Y.	89 E. Ave.
Rockford, Ill.	110 S. First St.
Rutland, Vt.	38½ Center St.
Sacramento 14, Calif.	626 Forum Bldg.
Saginaw, Mich.	Second National Bank Bldg.
St. Louis 1, Mo.	818 Olive St.
Salt Lake City 9, Utah	200 S. Main St.
San Antonio 5, Texas	434 So. Main Ave.
San Diego 1, Calif.	1240 Seventh Ave.
San Francisco 6, Calif.	235 Montgomery St.
San Jose 10, Calif.	460 Park Ave.
Savannah, Ga.	4 E. Bryan St.
Seattle 4, Wash.	710 Second Ave.
Seattle 8, Wash.	Avia. & Def., 220 Dawson St.
Shreveport, La.	206 Beck Bldg.
Sioux City 13, Iowa	572 Orpheum Electric Bldg.
South Bend 1, Ind.	112 W. Jefferson Blvd.
Spokane 4, Wash.	S. 162 Post St.
Springfield, Ill.	607 E. Adams St.
Springfield 3, Mass.	1387 Main St.
Stockton, Calif.	11 So. San Joaquin St.
Syracuse 6, N. Y.	3532 James St.
Tacoma 1, Wash.	1202 Washington Bldg.
Tampa 6, Fla.	1206 North A St.
Toledo 4, Ohio	420 Madison Ave.
Trenton 8, N. J.	214 E. Hanover St.
Tucson, Ariz.	P.O. Box 710, 650 N. Sixth Ave.
Tulsa 3, Okla.	320 S. Boston Ave.
Utica 2, N. Y.	258 Genesee St.
Washington 5, D. C.	777-14th St., N.W.
Waterloo, Iowa	206 W. 4th St.
Wenatchee, Wash.	328 N. Wenatchee Ave.
Wheeling, W. Va.	40 Fourteenth St.
Wichita 2, Kan.	200 E. First St.
Williamston, N. C.	115 E. Main St.
Worcester 5, Mass.	288 Grove St.
York, Pa.	56 N. Harrison St.
Youngstown 5, Ohio	272 E. Indianola Ave.

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